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A METHOD OF PREDICTING TUNA CATCH BY USING COASTAL SEA-SURFACE TEMPERATURES[1]

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INTRODUCTION

From its start nearly 60 years ago the California tuna fishery has grown into the state's largest fishery, both in value and in pounds landed (Power, 1960). Yellowfin tuna (*Neothunnus macropterus*) and skipjack (*Katsuwonus pelamis*) now are the two most important species and comprise the bulk of the California tuna landings. These are tropical tunas and seldom enter California waters in commercial quantities, the greatest portion of the catch being made by large bait boats and purse seiners operating off Mexico, Central America and South America.

In contrast to the distant fishery supported by yellowfin and skipjack is the fishery for the temperate tunas, albacore (*Thunnus germo*) and bluefin (*Thunnus saliens*). During the summer and fall, both of these species occur off the California and Baja California coasts where they are taken by many boats incapable of making the long trips to the tropics. Baitfishing and trolling produce the major portion of the albacore catch, whereas the bluefin is almost exclusively a purse-seine fishery. For detailed accounts of these methods see Godsil (1938) and Shimada and Schaefer (1956) on baitfishing, Scofield (1956) on trolling, and Whitehead (1931), Scofield (1951) and Orange and Broadhead (1959) on purse seining.

The catches from the California albacore and bluefin fisheries have varied markedly from year to year. The author, and other researchers, feel that some of this variation has been attributable to changes in the ocean climate off the California coast. The present study attempts to relate fluctuations in the temperate tuna catch (bluefin and albacore) to environmental conditions as measured by sea-surface temperatures at two shore stations in southern California.

ERRORS IN ESTIMATING AVAILABILITY FROM CATCH RECORDS

The majority of the local tuna catch has been made during the summer months. The seasonal nature of the California tuna fishery indicates that fluctuations in catch due to changes in the geographical distribution of the fish are of major importance. Some of this variation may be due to changes in the behavior of the fish rather than their actual absence from California waters. Present knowledge makes it

[1] Submitted for publication March, 1961.

difficult, if not impossible, to distinguish between fluctuations caused by absence and those caused by behavioral differences. For this study, no attempt is made to separate these two causes. Instead it is assumed that two populations of tuna, one of albacore and one of bluefin, are so located that during the summer months their ranges include the waters off southern California. The degree of presence (availability) of these populations is sampled by their respective fisheries. This method of sampling is subject to errors introduced by inclement weather and changes in the economy. Both of these errors can be treated as part of the sampling error. Variations in landings due to changes in population size (abundance) can also be treated as a randomly distributed sampling error.

An additional source of variation in the landings may be attributed to changes in the size of the fishing fleet. The error from this source can not be randomly distributed for the number of boats in both the albacore and the bluefin fleets has declined since the 1940's, but variations due to changes in fleet size are assumed to be small.

DISTRIBUTION OF CATCH

According to Clemens (1955), the usual albacore season starts around the middle of June. During the three years covered in his report, 1951-1953, the first catches were made in the vicinity of Cedros and Guadalupe Islands. As the summer progressed, the fishery moved up the coast terminating in the fall with the majority of the catches being made north of Point Conception.

During the spring of 1960, the Bureau of Commercial Fisheries, San Diego Biological Laboratory, in cooperation with the U. S. Navy, initiated an offshore albacore survey. Trolling gear was placed aboard five radar picket vessels stationed about 250 miles offshore from southern California to Washington. The early season catch as reported by these ships seemed to follow the northward and inshore march of the 59 degree isotherm (Johnson, 1960). Apparently the northward movement of the fishery reported by Clemens is related to sea temperature. This concept was originally developed by Thompson (1917), who utilized mean minimum aid temperature data from maritime stations as an index of sea temperature. He observed a striking correlation between observed temperatures and the northward movement of the fishery. Recently, Radovich (1961) has pointed out that movement of the fishery is related to temperature.

It is common knowledge that the bluefin fishery develops further south than the albacore fishery, often starting in June near Cape San Lazaro, Baja California, and shows a similar northward movement later in the season. Catches are made off southern California in the late summer and early fall (Skogsberg, 1925). Schools are reported north of Point Conception, but the catch from this area is negligible.

That temperature does play an important role in the movements of these fishes was dramatically shown by changes in the catch localities for albacore and bluefin during the recent warm period 1957 to 1960. Sea-surface temperatures during these years ranged 4 degrees F. higher than the 10-year mean (McGary, 1960). The usually large fishery for albacore off Baja California failed; it developed instead several hun-

Hred miles to the north. At the same time, the bluefin catch off southern California increased, resulting in the largest landings from California waters since the late 1940's. The striking contrast between the most productive bluefin areas in August 1952 and 1953, two years of cold water temperatures, and August 1957 and 1958, is shown in Figure 1. The data came from tuna seiner logbooks maintained by the fleet since 1952 for the Inter-American Tropical Tuna Commission.

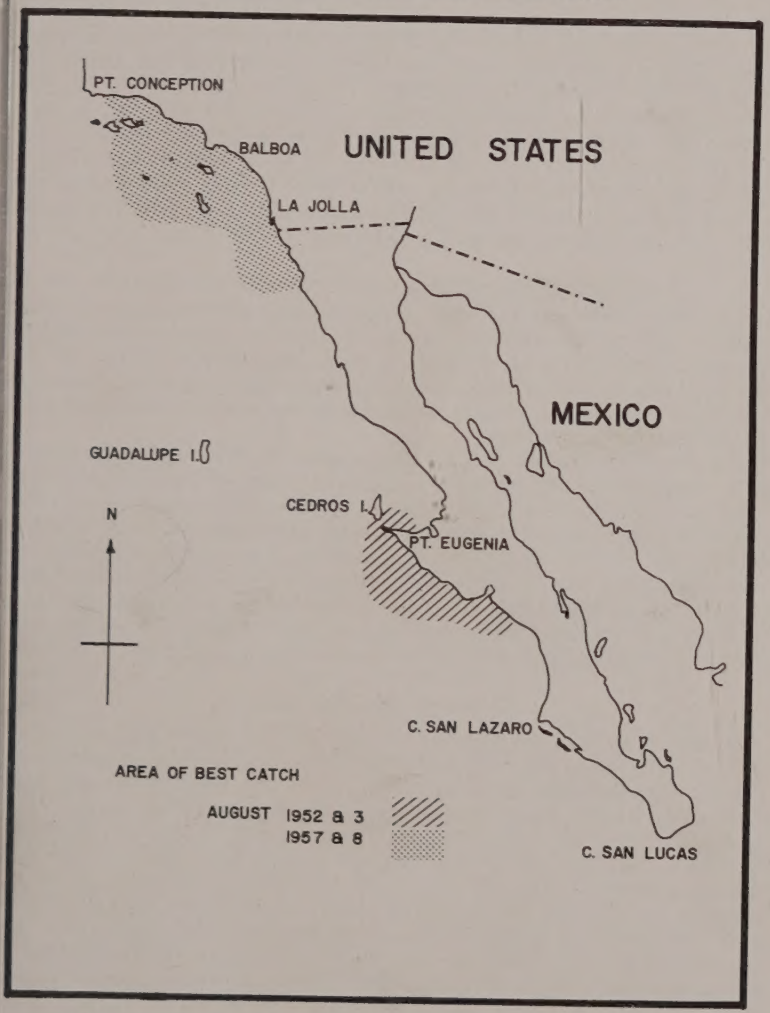

FIGURE 1. Changes in the most productive areas for bluefin fishing between August 1952 and 1953 and August 1957 and 1958.

TEMPERATURE EFFECTS

Any attempt to postulate some particular optimum temperature for albacore would have to explain the difference of several degrees in water temperature existing between our troll fishery and the Japanese pole and line fishery. The best Japanese catches occur in waters warmer than off California (Calif. Mar. Res. Comm., 1960, Murphy). The reverse seems to be true for bluefin, as the Japanese net fishery is conducted at a lower temperature than ours (Uda, 1957). In this case, however, a different population of bluefin tuna may be involved since trans-Pacific migrations have not been demonstrated for bluefin as they have for albacore (Otsu, 1960).

It is possible that temperature affects the behavior of a fish in such a way that the best catches for particular types of gear occur at different temperatures. For example, there is some indication that bait-fishing for albacore is more successful later in the season when the schools are more concentrated. This concentration of schools may be related to the higher water temperatures which occur later in the season.

Several indirect effects might influence the capture of tunas. One is the increased basic productivity found in areas of upwelling. Schaefer (1957) also points out that areas of tropical tuna concentrations appear to coincide with regions of high basic productivity. An increase in the amount of tuna food in an area could result in a temperature-tuna relationship seemingly dependent upon the cooler water associated with the upwelling.

High productivity as well as other factors which may be correlated with temperature can produce changes in water clarity and these in turn may influence fishing success. Some attempts have been made to relate fishing success to turbidity (Whitehead, *op. cit.* and Murphy, 1959). The latter relates albacore catch to underwater visibility on the assumption that troll caught albacore are sight feeding. Thus trolling success might be poor in the turbid coastal water close to shore, whereas net fishing for bluefin may depend upon poor underwater visibility resulting in better catches near shore and at night.

CHANGES IN LANDINGS

Yearly tuna landings are reported by the California Department of Fish and Game in its *Fish Bulletin* series. The catch is divided into fishing boat landings from waters north of the California state line, California waters, and waters south of the International Border. The total landings from 1945 through 1959 are given in Table 1. The cut-off date, 1945, was chosen in order to exclude some of the economic factors present during the war years. In addition to total landings, albacore and bluefin landings from south of the International Border and from California waters have been provided. An increase in the bluefin catch from California waters was coincident with the warm-water conditions in 1957 and 1958. For comparison, tropical tuna landings from California waters also have been given in Table 1. The presence of commercial quantities of these fish in California waters may be regarded as a further indication of changes in the oceanic

TABLE 1

Landings in Millions of Pounds for Bluefin and Albacore
Thousands of Pounds for Yellowfin and Skipjack [1]

Year	Total California albacore landings*	Total California bluefin landings	Landings from south of the International Border		Landings from California waters			
			Bluefin	Albacore	Albacore	Bluefin	Yellowfin	Skipjack
1945	21.77	20.59	6.45	12.26	8.78	14.14	4.96	93.08
1946	18.06	22.03	6.50	8.96	9.10	15.53	32.65	1,747.06
1947	13.14	20.83	6.07	5.76	7.40	14.76	3.32	893.05
1948	36.42	6.53	4.84	25.93	10.50	1.69	0.41	319.19
1949	44.02	4.39	2.12	23.58	20.40	2.27	9.88	26.68
1950	61.75	2.74	2.73	23.60	38.14	0.01	1.46	12.42
1951	30.68	3.86	3.02	17.62	13.28	0.84	0.00	0.59
1952	49.79	4.58	3.67	26.70	23.10	0.91	0.00	0.53
1953	33.83	9.17	5.87	20.49	13.30	3.90	0.10	1.28
1954	26.11	21.02	15.37	11.82	14.29	5.65	0.00	14.40
1955	29.00	13.61	11.13	19.69	9.31	2.48	0.00	1.24
1956	37.04	12.62	10.01	21.06	15.87	2.61	0.10	0.88
1957	43.47	20.31	9.85	20.91	22.61	10.46	70.85	353.46
1958	27.10	30.72	15.11	0.72	25.39	15.61	417.71	2,488.91
1959	32.74	15.30	2.17	0.00	32.52	13.13	81.68	1,380.96

[1] Source—Calif. Dept. Fish and Game, Marine Resources Operations.
* Includes some fishing boat landings from north of the state line.

climate off California. The data were plotted (Figure 2) using fishing boat landings reported from California waters for skipjack, yellowfin, and bluefin, and landings from waters south of the International Border for albacore. The figure indicates that a change took place towards the end of the 1940's which was reversed in 1957. This change was characterized by a decline in skipjack, yellowfin, and bluefin landings, and a rise in albacore. The rise in the albacore catch and the decline in bluefin are most interesting. Since the two fisheries are essentially independent, albacore being caught with hook and line and bluefin being netted, fluctuations due to fishermen's preference for one species over the other are eliminated.

This relationship can be explained by postulating two population centers, one for albacore and one for bluefin. These centers of abundance, which are indicated by the best catches for the two species, do not coincide, bluefin occurring south and inshore of albacore. During cold years, the center of the albacore population would move south resulting in higher catches south of the International Border. Logbook records show that substantial catches of albacore were made off Baja California during the early 1950's when bluefin were rare north of Cedros Island. During warm years, the albacore would move northward resulting in lower catches in the southern fishery. At the same time, the center of the bluefin population also would move northward resulting in increased bluefin catches in California waters. The relationship is examined in more detail in Figure 3 where southern albacore catches and northern bluefin catches have been plotted against each other. A northward movement of bluefin should be accompanied by an increase in bluefin catch and a decrease in albacore catch.

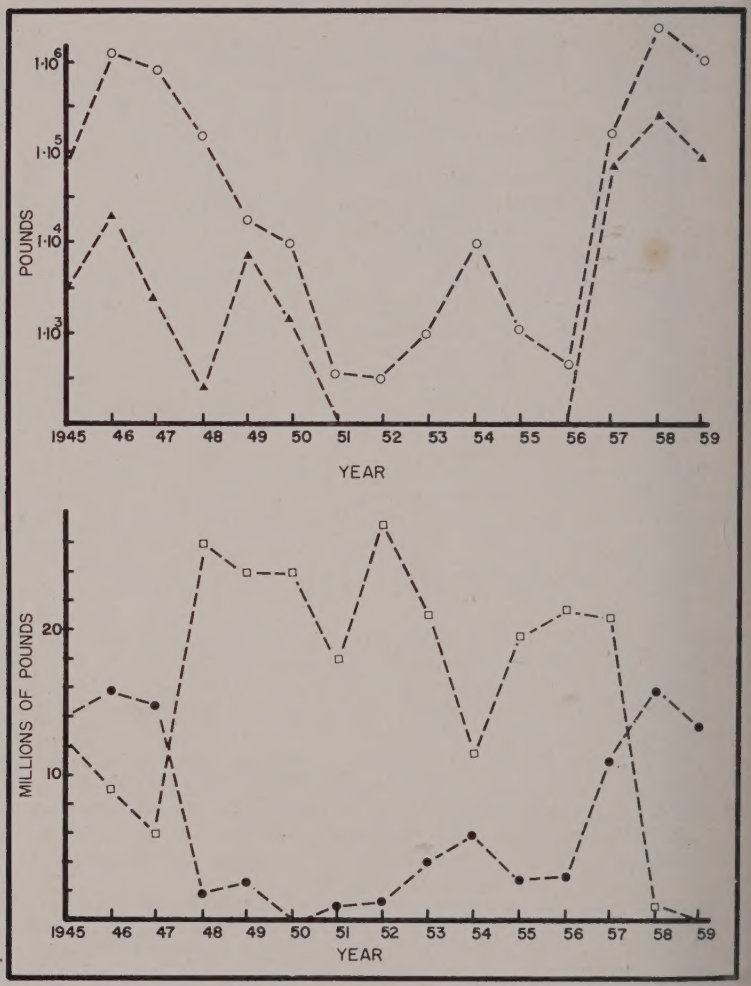

FIGURE 2. Top: *Skipjack*—fishing boat landings from California waters, open circles. *Yellowfin*—fishing boat landings from California waters, closed triangles. Bottom: *Albacore*—fishing boat landings from waters south of the International Border, open squares. *Bluefin*—fishing boat landings from California waters, closed circles.

A high inverse correlation exists between bluefin and albacore catches as is shown by a correlation coefficient of —0.84. This coefficient can be interpreted to mean that 84 percent of the fluctuations in landings between the two species are due to some common element. In this case it is assumed that the common element is movement of the fish populations due to environmental factors.

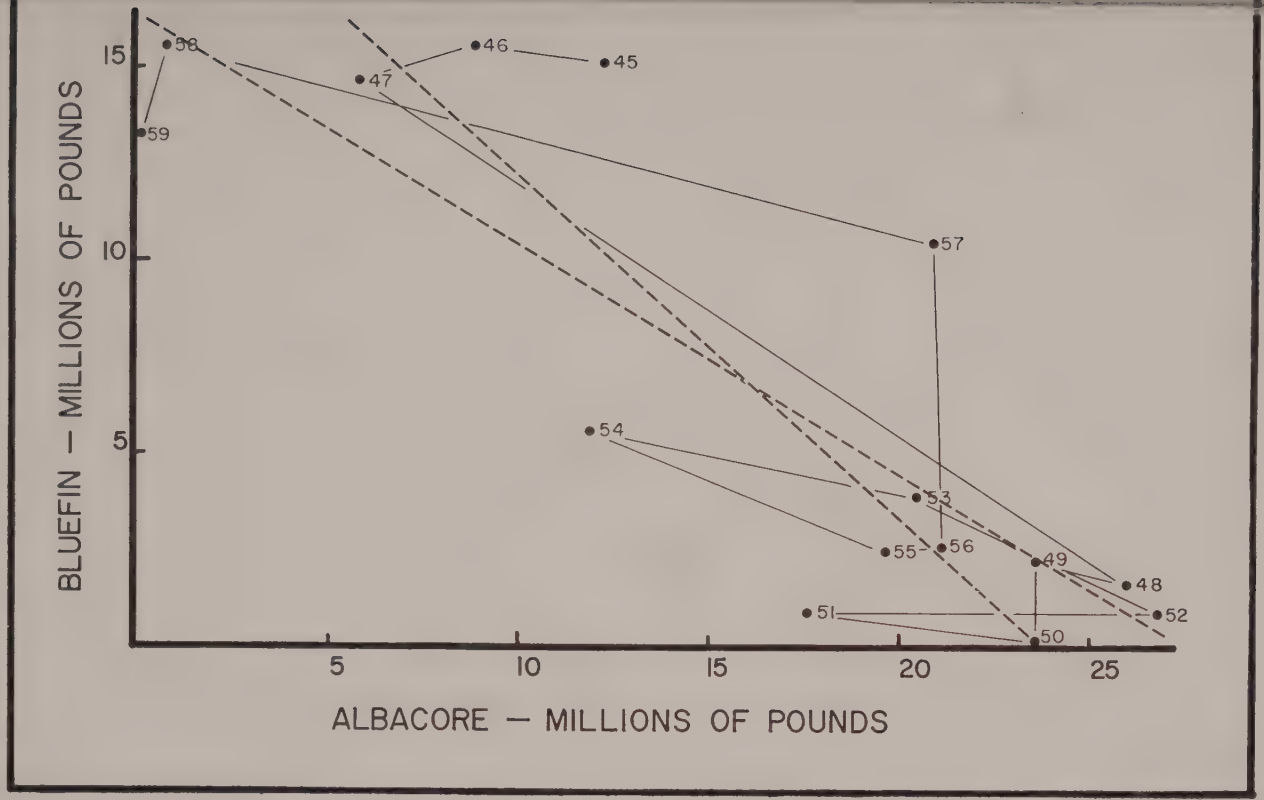

FIGURE 3. *Albacore*—fishing boat landings from south of the International Border. *Bluefin*—fishing boat landings from California waters. Numbers on graph are years 1945 through 1959.

TEMPERATURE AS AN INDEX OF AVAILABILITY OF ALBACORE AND BLUEFIN

A source for sea temperature data covering the same period and areas as the catch is difficult to find. Since 1949, California Cooperative Oceanic Fisheries Investigations (CCOFI) has run a series of station lines from San Francisco to Cape San Lucas but the coverage is missing for certain key months. Sea-surface temperatures collected by the U. S. Weather Bureau are sparse prior to 1950. However, sea-surface temperatures are available from shore stations along the California coast back to 1935. These data have been collected by the University of California, Scripps Institution of Oceanography, under a program initiated by Dr. George F. McEwen. Observations from the two stations south of latitude 34° N., La Jolla, and Balboa Pier, have been averaged for use in this study (Table 2). Although these shore stations are in the northern part of the area to be considered, they probably will provide an index to environmental changes in the sea off southern California and northern Baja California. This is due to the common circulation of the waters from Point Conception to Point Eugenia (Calif. Mar. Res. Comm., 1958).

The bulk of the local tuna has been caught during July, August and September. A comparison has been made in Figure 4 between the annual catch of bluefin from California waters and albacore from waters south of the International Border, and the sea-surface temperatures at Balboa and La Jolla averaged together for these three months. Two lines were fitted by the method of least squares, *A-A'* for albacore and *B-B'* for bluefin. The equation for *A-A'* is:

$$1)\quad A_s = 163.84 - 7.65T_s$$

where A_s is the estimated albacore catch (millions of pounds) south of the International Border and T_s is the average surface water temperature (degrees Centigrade) July through September at Balboa and La Jolla. The standard error of an estimated catch is 7.412 and the standard error of the slope is 2.68. The equation for *B-B'* is:

$$2)\quad B_s = -112.32 + 6.17T_s$$

where B_s is the estimated bluefin catch (millions of pounds) from California waters and T_s is as above. The standard error of an estimated catch is 4.607 and the standard error of the slope is 1.66. The slope of the line in equation (1) is significant at the 5 percent level, the slope in equation (2) at the 1 percent level. The inverse relationship between the bluefin and albacore catch is apparent.

A study of year to year temperature changes indicates that warm years along the southern California coast are preceded by warm water temperatures in winter. This has been attributed to increased advection from the south during the winter months (Calif. Mar. Res. Comm., 1953) and other causes. The relationship between winter and summer temperatures provides a convenient way to predict unusually good or bad years for the local tuna fishery. In Figures 5 and 6, the southern albacore and northern bluefin catches were plotted against Balboa and La Jolla sea-surface temperatures averaged together for the months

TABLE 2

Sea-Surface Temperatures, Degrees Centigrade, for the Years 1945 Through 1959 at La Jolla and Balboa

Year	Yearly mean		SUMMER							WINTER								
			Mean-La Jolla			Mean-Balboa			Summer mean	Mean-La Jolla				Mean-Balboa				Winter mean
	La Jolla	Balboa	July	Aug.	Sept.	July	Aug.	Sept.	La Jolla + Balboa	Jan.	Feb.	Mar.	Apr.	Jan.	Feb.	Mar.	Apr.	La Jolla + Balboa
1945	16.61	16.20	20.02	21.39	20.31	18.78	19.77	19.36	19.94	14.17	13.99	13.09	13.82	14.27	14.31	13.34	13.94	13.87
1946	16.83	16.62	20.39	21.21	18.89	20.00	19.69	19.04	19.87	13.03	12.78	13.63	16.17	13.49	13.29	13.53	15.96	13.98
1947	16.88	16.78	19.29	20.01	19.56	19.10	20.30	19.01	19.54	13.45	13.86	14.87	15.76	13.67	14.03	15.05	15.89	14.57
1948	16.08	15.62	18.47	19.86	19.31	17.98	18.15	18.41	18.70	13.56	13.14	13.41	14.80	13.44	12.78	13.30	14.29	13.59
1949	16.52	15.97	20.15	20.86	20.19	18.95	19.24	18.62	19.67	12.28	12.66	13.42	14.40	12.13	12.31	12.96	14.37	13.07
1950	16.40	15.85	20.54	19.11	19.31	18.64	18.16	18.83	19.10	12.76	12.97	13.91	15.67	12.56	12.82	13.81	15.06	13.70
1951	16.62	15.78	20.14	19.69	17.77	18.85	17.84	16.80	18.52	13.25	13.48	13.99	15.99	13.05	13.44	13.33	15.06	13.95
1952	16.28	15.31	18.06	20.90	18.12	16.25	18.32	16.21	17.98	13.71	13.59	13.46	15.42	13.21	13.41	12.94	14.89	13.83
1953	16.24	15.51	20.57	20.69	17.63	19.17	18.60	16.36	18.84	13.97	13.18	13.65	14.60	13.74	13.01	12.86	13.75	13.60
1954	16.86	15.02	21.25	21.26	19.10	17.91	17.27	16.29	18.86	14.10	14.32	14.03	15.06	14.05	14.42	13.84	15.24	14.38
1955	16.48	15.34	19.60	21.48	20.58	18.11	17.62	17.92	19.22	13.38	12.95	14.35	14.14	13.55	12.51	14.29	12.99	13.52
1956	16.37	15.69	19.96	21.08	18.82	18.27	19.69	17.40	19.20	12.61	12.89	13.36	14.77	12.60	12.68	13.37	14.15	13.30
1957	17.36	16.48	20.87	21.55	19.15	19.87	20.75	18.44	20.10	14.81	14.34	14.83	15.29	14.56	14.06	14.83	13.75	14.56
1958	17.84	17.43	19.39	20.49	20.21	18.32	19.54	19.49	19.58	16.06	16.00	15.34	17.06	15.82	15.86	15.32	17.11	16.07
1959	18.35	17.71	21.95	21.27	21.01	20.29	18.90	20.27	20.84	16.00	15.21	16.19	17.02	15.49	15.02	15.96	16.22	15.89

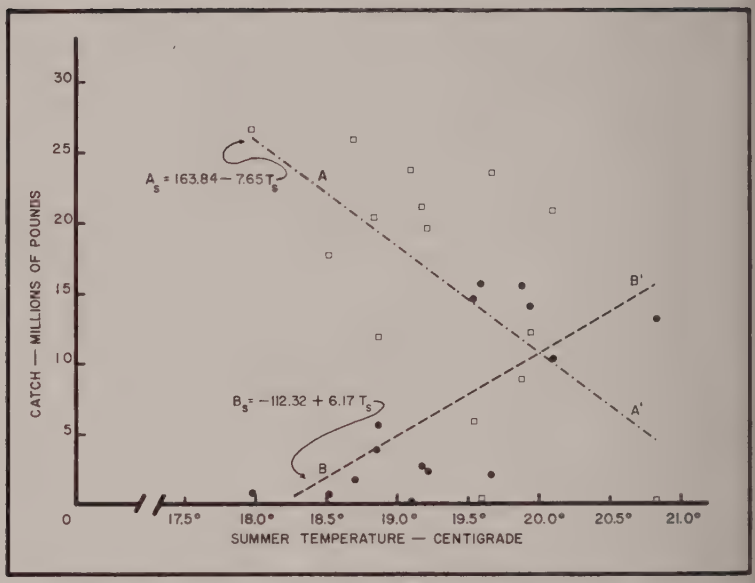

FIGURE 4. *Albacore*—yearly fishing boat landings from waters south of the International Border, open squares. *Bluefin*—yearly fishing boat landings from California waters, solid circles. *Temperature*—average July, August and September sea-surface temperature, Balboa and La Jolla.

January through April for each of the years 1945 through 1959. Lines were fitted to the data and the equations are:

$$3)\quad A_w = 135.11 - 8.44T_w$$

where A_w is the estimated albacore catch south of the International Border and T_w is the average winter sea-surface temperature January through April at Balboa and La Jolla. The standard error of an estimated catch is 5.324 and the standard error of the slope is 1.79;

$$4)\quad B_w = -61.41 + 4.84T_w$$

where B_w is the estimated bluefin catch from California waters and T_w is as above. The standard error of an estimated catch for bluefin is 4.853 and the standard error of the slope is 1.45. Both slopes are significant at the 1 percent level. Of interest is the reduction in standard error for both species, implying a closer tie between winter conditions and subsequent events than between the simultaneous events, catch and summer water temperature, shown in Figure 4.

The relation does suggest temperature as an easily measured indicator on which to base predictions. The statistical validity of the preceding is based on the assumptions that the temperatures are measured without error, that the variations in catch due to sampling by the fishery are normally distributed about some mean value, and that the standard deviations for the catch at each temperature are equal. The temperature for any year was the average of over 200 observations and errors from this source should be minimal.

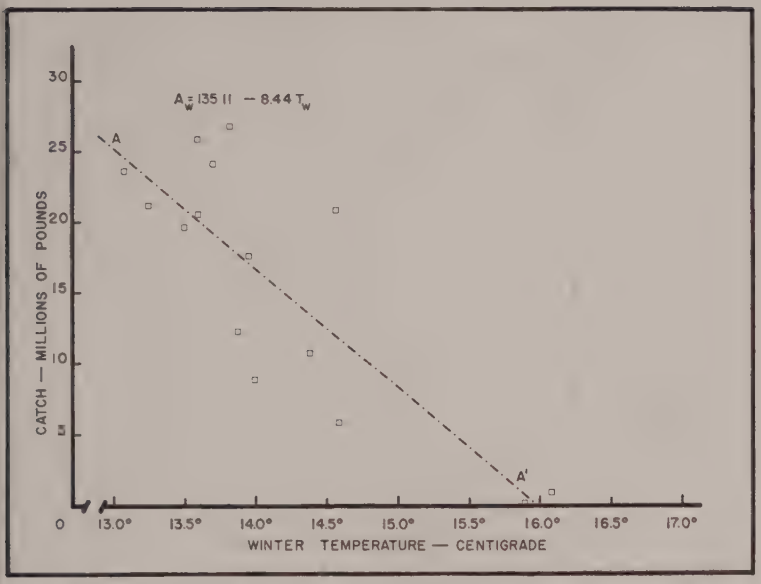

FIGURE 5. *Albacore*—fishing boat landings from waters south of the International Border. *Temperature*—average sea-surface temperature January through April, Balboa and La Jolla.

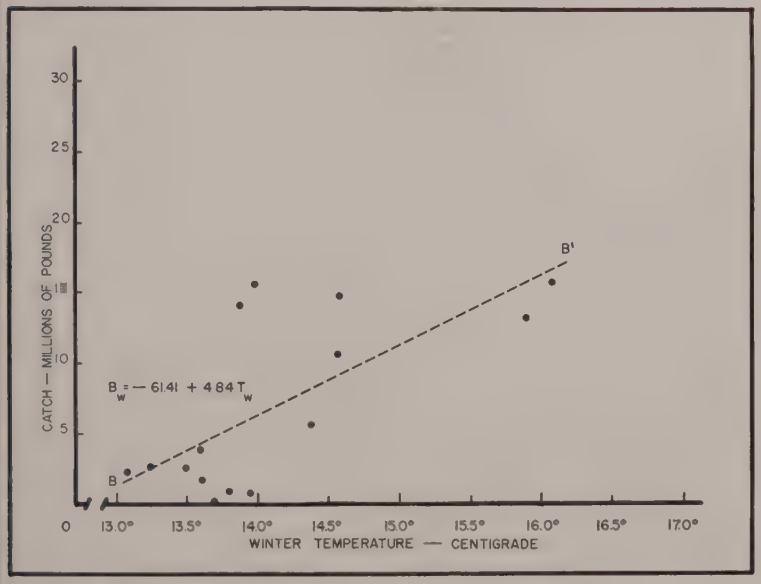

FIGURE 6. *Bluefin*—fishing boat landings from California waters. *Temperature*—average sea-surface temperature January through April, Balboa and La Jolla.

By accepting the preceding assumptions, it now should be possible to make catch predictions based on temperature. For example, the four-month average winter water temperature for Balboa and La Jolla during 1960 was 14.35 degrees C. From equation (4) we would then estimate the 1960 California bluefin catch to be 8.0 million pounds and from (3) we would estimate the albacore catch south of the International Border to be 13.9 million pounds. Fiducial limits at about the 66 percent probability level would be 3.2 to 12.8 million pounds for bluefin. Similarly, we can estimate that the 1960 albacore landings from waters south of the International Border will lie between the 66 percent confidence limits of 8.5 and 19.3 million pounds. The actual landings for 1960 are not yet available from the California Department of Fish and Game, so it is not possible to check our forecast. Preliminary reports, without regard to area of catch, indicate that the bluefin figure should be close. An early season tie-up by the albacore fleet will probably result in an over-estimate for the albacore prediction. However, since the equations were derived from data that were uncorrected for economic factors, the source of error due to the tie-up should be already included in our confidence limits.

FORECASTING TOTAL CATCH

So far only catches from limited areas have been considered. An attempt to predict total California landings from sea-surface temperatures is more involved. Total California albacore landings (Table 1) are made up of fish from south of the International Border, fish from California waters, and fish from north of the California state line. Although temperature might influence the movements of the fish in the latter two areas, the errors, which before could be treated as random sampling errors, become large north of the International Border. This is primarily due to large changes in fleet size depending on the success of the salmon troll fishery and the southern albacore fishery. The effect of weather probably is important too and would produce greater variability in the size of the catch north of Point Conception. For this reason an average of the 15-year landings is probably the best available estimate for the landings from California waters for any year. This average is 17.60 million pounds. Until a pre-season measure of changes in effort is available for the albacore fishery, a closer estimate of total catch cannot be made.

Total bluefin landings closely follow the trend of the landings from California waters. The relationship between total bluefin landings and winter water temperature is given by:

$$5)\ B_t = -76.52 + 6.40T_w$$

where B_t is total bluefin landing in millions of pounds and T_w is the winter sea-surface temperature previously described. The standard error of an estimated catch is 6.947. The standard error of the slope is 2.08. The slope is significant at the 1 percent level. The total estimated California bluefin catch for 1960 is 15.32 $\pm$ 6.9 million pounds at the 66 percent confidence level.

SUMMARY

1. Tuna landings from southern California waters fluctuate from year to year both in quantity and area of capture.

2. A correlation has been shown between sea-surface temperature (July, August, and September mean) at two southern California shore stations and bluefin and albacore catch from selected areas.

3. This correlation holds when winter water temperatures are used permitting a forecast of bluefin and albacore catch before the season begins.

4. Equations have been given for predicting any year's bluefin and albacore catch in selected areas and limits of confidence are set.

5. Landings from the selected areas have been compared with total California landings.

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A MECHANICAL NET-PULLER FOR SKIFF FISHING WITH GILL NETS[1]

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INTRODUCTION

For years Marine Resources Operations personnel felt the need for a mechanical net-puller. The usual "armstrong" method of retrieving involved from four to six men and was anything but economical. The use of large crews normally necessitated "borrowing" personnel from other projects to supplement the small number of men normally engaged in any particular investigation. This practice was usually satisfactory but one could not always depend upon obtaining extra men when needed.

Personnel of the Barracuda and White Seabass Management Study, Dingell-Johnson project F-16-R, procured samples of project species in several ways: from the sport and commercial fisheries in southern California waters, and with gill nets, beach seines and hook and line. Local samples were normally procured from the existing fishing industries but on occasion specimens of sizes not captured by the commercial fisheries had to be taken with sampling nets. On survey trips into Mexican waters, however, procuring samples required extensive use of gill nets. During the project's first Mexican cruise in October 1958 it required two to four men to retrieve gill nets by hand. The large crew effectively limited the amount of gear that could be handled in the skiff at one time and necessitated frequent returns to the research vessel to unload.

A second survey cruise to Mexican waters was planned for January and February 1960, at which time widespread sampling for white seabass in the upper Gulf of California was proposed. The large area to be covered by the survey and the short hours of daylight at that time of year pointed up a need for greater efficiency in handling gill nets, our main sampling tool. Project personnel felt the best way to speed up the operation would be to develop a net-puller so that nets could not only be lifted faster but could be fished in much deeper water than was formerly possible.

RESEARCH

A survey of equipment being used by commercial white seabass fishermen in southern California was conducted in the fall of 1959. That

[1] Submitted for publication July 1960. This work was performed as part of Dingell-Johnson Project California F-16-R, "Barracuda and White Seabass Management Study", supported by Federal Aid to Fish Restoration Funds.
[2] Since this article was written the author transferred to the Water Projects Branch.

thought to be the most suitable to the needs of the project was being used by skiff fishermen Tom Farmer around Santa Barbara and Theodore R. Phegley at Newport Beach. The net-pullers used by these fishermen were similar, differing mainly in the manner in which power was transmitted from the motor to the gurdy.

At Santa Barbara Mr. Farmer had his net gurdy powered by a three-horsepower Continental, air cooled, gasoline engine (Figure 1). Power was transmitted by direct drive through an Ohio reduction gear to the gurdy. A mechanical clutch was placed between the engine and reduction gear to enable the lone operator to disengage the gurdy when removing fish from the net.

The net rollers used on the skiff were made of redwood covered with fiberglass. The rollers were mounted on a hinged base so that the unit could be swung inboard when the boat was under way.

Nets were pulled across the rollers on the port side of the boat by winding them around the gurdy directly opposite on the starboard side. When a fish was encountered in the net, the gurdy was disengaged, the fish removed and the operation continued.

Nets were set over the starboard side of the stern around a vertical guide roller, used to keep them from becoming entangled in the outboard motor.

Mr. Phegley's skiff is used for white seabass fishing at Newport Beach and has a net gurdy powered by a three-horsepower Briggs and

FIGURE 1. Outboard powered skiff, owned and operated by Tom Farmer of Carpinteria, California, used for white seabass fishing in the Santa Barbara area. *Photograph by the author, October, 1959.*

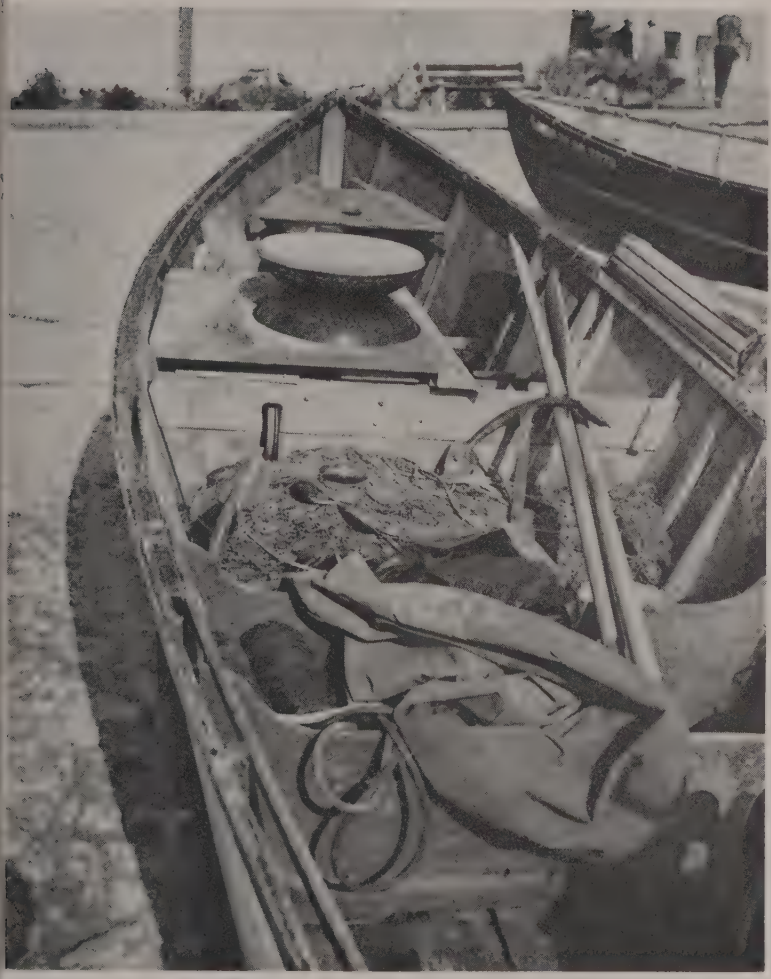

FIGURE 2. Surf skiff, owned and operated by Theodore R. Phegley of Costa Mesa, California, used for white seabass fishing in the Newport Beach area. *Photograph by the author, October, 1959.*

Stratton, air cooled, gasoline engine (Figure 2). This gurdy instead of having direct drive was driven by v-belts and speed was reduced by pulleys instead of a reduction gear. A truck steering knuckle was used to give the necessary 90 degree angle drive to the gurdy head.

Nets were fished from this skiff in much the same manner as they were by the Santa Barbara fisherman but the gurdy was mounted on the left side of the boat instead of the right. The net roller was different, being constructed of hardwood strips fastened to spacers

turning on a pipe axle. No guide rollers were employed. This skiff was also operated by one man. For economy, the clutch was dispensed with; fish removal was effected by simply lifting the net off the gurdy until the fish could be disentangled.

Nets were set over the side of the skiff and here also a vertical guide bar was used to keep them away from the outboard motor.

DEVELOPMENT

The net gurdy we developed (Figure 3) incorporated many of the features of the commercial gurdies but was adapted to our particular needs by being self-contained so it could be removed from the skiff when not in use. The gurdy was powered by a three-horsepower Briggs and Stratton, aluminum block, air cooled, gasoline engine. This engine was chosen because of initial low cost and ready availability of spare parts. Power is transmitted from the engine to the reduction gear by a double v-belt drive. A speed reducer having a gear ratio of 35 : 1 was installed. The engine geared down through a 6 : 1 reduction gear, developed a driveshaft speed of 600 r.p.m. which was further reduced by a ratio of 2 : 1 in the pulleys, giving a final speed of 28 r.p.m. at the gurdy head. This speed is ideal for pulling nets. The gurdy head was constructed of two steel tank ends, vulcanized and bolted together with a wooden spacer. The wooden spacer was used to keep anchor lines from cutting through the vulcanized gurdy faces.

The components were mounted on a piece of aluminum alloy deck plate with aluminum channel brackets. The cover framework was constructed of aluminum angle material and the entire unit was covered with one-fourth-inch marine plywood to keep nets from becoming entangled in the machinery and to keep excess salt water off the motor.

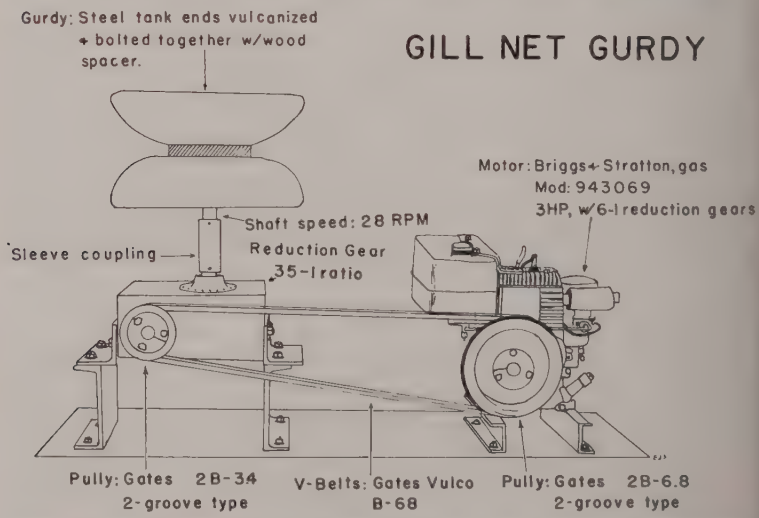

FIGURE 3. Sketch of gill net gurdy showing component parts. Channeled framework and plywood covering not included.

The assembled unit weighed approximately 150 pounds but could have been made lighter with several modifications. Instead of housing the reduction gear in a steel case, as we did, aluminum could have been used. A smaller unit such as a Bond speed reducer, Series QV or OEV, could have been used and by all calculations would have produced sufficient torque. This substitution would have cut the weight by at least 20 pounds. Steel tank ends were used in constructing the gurdy head but it was felt that aluminum could have been used just as well.

The project's net-puller employs a v-belt drive without the benefit of a clutch, which was found to be unnecessary. However, with but a slight modification an idler pulley used as a clutch could be installed between the motor and reduction gear. An alternate arrangement would be to use a standard Briggs and Stratton motor developing a shaft speed of 3,600 r.p.m. and having a centrifugal clutch. The gurdy would then be disengaged when the speed of the motor was reduced. With this plan a pulley speed reduction of 1:3.3 would work satisfactorily. A centrifugal clutch would also add a safety feature in that the clutch would disengage whenever the gurdy was overloaded and the speed of the engine was reduced to half of its normal operating speed.

The vulcanized gurdy head was designed to pull nets and would be a little awkward if used exclusively to pull beach seines and crab or lobster pots. When handling only lines it would be more practical to substitute a standard metal drum for the rubber one so that lines could be slacked off when necessary, a difficult feat if more than one turn was taken around the wooden spacer of the net gurdy. When handling lines exclusively a higher gurdy speed is desirable and this could be effected by changing the diameters of the pulleys.

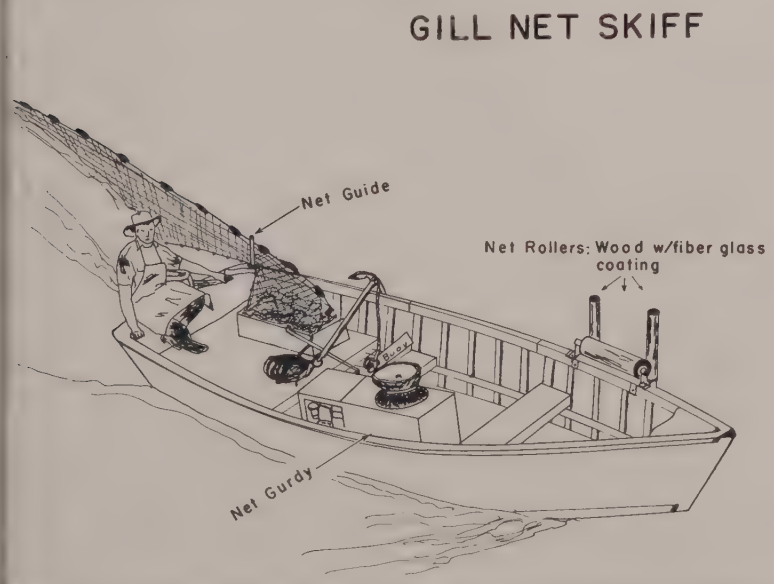

FIGURE 4. Sketch of gill net skiff showing method of setting net and placement of equipment.

FIGURE 5. Gill net skiff showing anchor line coming aboard. *Photograph by Leo Pinkas, January, 1960.*

The net rollers we installed were constructed of solid wood covered with fiberglass. They were mounted in a fixed position (Figure 4) on the left side of the skiff. It was found, however, that as originally mounted they were too far forward (Figure 5). For most efficient operation they should be positioned so the middle of the horizontal roller would be at right angles to the forward edge of the gurdy.

The pulling power developed by the unit was estimated to be greater than 6,000 inch-pounds of torque, more than sufficient for the intended use.

The sketch (Figure 4) and photograph (Figure 5) show placement of the net gurdy for the gill net operations. The unit was made longer than necessary so it could be bolted securely to the thwarts, but for other applications the entire unit could be shortened by one-fourth without sacrificing efficiency. The reduction gear could also be mounted above the motor effectively.

DISCUSSION

By using a net-puller, gill netting required but two men for satisfactory operation. One man was sufficient for handling the net and skiff but the collection of other scientific data necessitated another man. During the cruise to the Gulf of California an average of five nets a night were set in from 3 to 180 feet of water. The net gurdy not only allowed us to fish deeper than was previously possible but the time

ved in the operation permitted our engaging in other types of sam-
ing.

SUMMARY

A mechanical net-puller or gurdy was developed by Dingell-Johnson roject F-16-R to assist in fishing with gill nets to obtain samples of oject species. Fishing gill nets by hand had proved difficult and time nsuming in deep water and required a two to four man crew. The t-puller enabled fishing with gill nets to a depth of 180 feet and it as felt they could have been fished deeper. By using the gurdy, one an could handle the nets. The gurdy was also found useful for pulling ach seines and lobster pots and with slight modification its efficiency r these purposes could be greatly increased.

OCCURRENCE OF THE ROUND STINGRAY, *UROLOPHUS HALLERI* COOPER, IN HUMBOLDT BAY, CALIFORNIA[1]

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INTRODUCTION

The round stingray was first described from the waters of San Pedro nd San Diego Bays by Cooper (1863, p. 95). Since then various uthors have redescribed the fish and recorded the areas of southern 'alifornia, Baja California and the Gulf of California in which it is 'ound. Garman (1913, p. 401) divided *Urolophus* into two genera, *Urolophus* and *Urobatis*, on the basis of disk shape. Bigelow and Schroeder (1953, p. 418) considered this differentiation as merely specific and relegated *Urobatis* to synonymy with *Urolophus*.

OCCURRENCE IN HUMBOLDT BAY

On May 12, 1960, while observing seining operations to eliminate bat rays (*Myliobatis californicus*) from the oyster beds of the Coast Oyster Company of California in north Humboldt Bay, Humboldt County, California, I collected a single male round stingray 408 mm. in total length. It was taken in a seine haul in one of the shallow sloughs that are characteristic of the bay. This capture extended the range approximately 290 miles in a northwesterly direction. The preserved specimen has been deposited in the California Academy of Sciences collection (CAS No. 26786).

The successful haul was made at approximately low water during a series of spring tides. The predicted low for Humboldt Bay on May 12 was —1.6 feet. At that stage, the water would probably not be more than six feet deep anywhere in the slough and generally would be considerably less.

RECORDED RANGE

The recorded range of *Urolophus halleri* has been given as Pt. Conception, California, south to Panama by most authors. These have been based on records of Hubbs (1920, p. 82), who took a single individual at Goleta, California, just north of Santa Barbara, and Jordan and Gilbert (1883, p. 621) who presented information on two specimens from Panama.

Herald (1953, p. 237) reported *Urolophus halleri* in Elkhorn Slough, Monterey Bay; the first record north of Pt. Conception. He stated that the estero at Goleta was the type locality; however, Cooper in his

[1] Submitted for publication September 1960.

original description (*op. cit.*, p. 95) did not specify a type-locality but inferred the mouths of muddy creeks of San Pedro and San Diego Bays were the preferred habitat. This was further emphasized by Holloway *et al.* (1953, p. 78) who stated that 125 specimens were easily obtained by seining a lagoon at Seal Beach, just south of San Pedro, and 12 were collected from Mission May, San Diego. Starks and Morris (1907, p. 172) reported it was the commonest stingray of San Diego Bay. Following Herald's report, Roedel (1953, p. 28) gave the range as Monterey Bay to Panama.

ASSOCIATED SPECIES

Captured in the same haul with the round stingray were:

20	brown smoothhounds	*Triakis henlei* (Gill)
1	leopard shark	*Triakis semifasciata* Girard
31	bat rays	*Myliobatis californicus* Gill
1	redtail surfperch	*Amphistichus rhodoterus* (Agassiz)
1	walleye surfperch	*Hyperprosopon argenteum* Gibbons
6	Pacific staghorn sculpins	*Leptocottus armatus* Girard
2	California halibut	*Paralichthys californicus* (Ayres)
10	starry flounders	*Platichthys stellatus* (Pallas)

The two halibut marked the first record for that species from within Humboldt Bay. Gunderson (1960, p. 373) previously reported them from the mouth of Humboldt Bay and further north on the open coast at Redding Rock and off the Klamath River. The two seined on May 12 in Humboldt Bay were 286 mm. and 340 mm. in standard length and were deposited in the California Academy of Sciences collection (CAS No. 26787).

The same day a sevengill shark (*Notorynchus maculatus* Ayres) was found stranded by low tide on an oyster bed approximately one mile from the seining site.

TEMPERATURES

The California Department of Fish and Game, in cooperation with the Coast Oyster Company of California, maintains a recording thermograph in the slough where the round stingray was collected. The temperature on May 12, 1960 was 55 degrees F. Average temperatures for the 10-day period May 3 through 12, 1960, and for several previous years were:

1956	56 degrees F.	1959	thermograph inoperative
1957	56 degrees F.	1960	56 degrees F.
1958	53 degrees F.		

The occurrence of a round stingray in Humboldt Bay fits in well with the recent movements of southern forms to more northerly areas (CCOFI 1958, p. 13; Radovich 1960, p. 163).

Herald *et al.* (1960, p. 60 and personal communication) recorded *Urolophus* in the Elkhorn Slough area of Monterey Bay in June or July of every year from 1952 through 1960, with the exception of 1957. Hydrographic surveys of Monterey Bay (CCOFI *op. cit.*, p. 17) indicated the early 1950's were cold-water years and 1957 produced the warmest water in more than a decade. The annual capturing of round

ingrays in Monterey Bay since 1952 probably reflects a better collect-
g method, i.e., intense concentration of hook and line fishermen,
ather than movements associated with warm waters.

Of the 13 round stingrays from Elkhorn Slough 10 were males,
a female, and 2 of unrecorded sex. On this basis, Herald *et al.* (*op.*
t., p. 65) suggested a probable separation by sexes during June and
uly. The capture of a male at Humboldt Bay supports this theory.
mong elasmobranchs, segregation of sexes has been demonstrated for
ie soupfin shark (*Galeorhinus zyopterus* Jordan and Gilbert) by
ipley (1946, p. 17) and for the blue shark (*Prionace glauca* (Lin-
aeus)) by Strasburg (1958, p. 351) who briefly reviewed behavioral
nd geographical sex-segregation among sharks.

SUMMARY

1. A male round stingray collected in Humboldt Bay May 12, 1960 extended their known range some 290 miles northward.

2. A preponderance of males in the northern portion of the range uring May, June and July suggests a separation by sex for that time f year.

3. Round stingrays apparently are annual visitors to Monterey Bay, ut were not recorded there until 1952.

ACKNOWLEDGMENTS

I wish to extend my thanks to the Coast Oyster Company of Cali-
ornia. The interest, enthusiasm and cooperation of the management
nd employees have made efforts to catalog the marine life of Hum-
oldt Bay a pleasure.

Appreciation is also expressed to Dr. Earl S. Herald and Mr. W. I.
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anuscript.

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OBSERVATIONS ON A DIE-OFF OF MOLAS (*MOLA MOLA*) IN MONTEREY BAY[1]

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Molas are noted for their almost worldwide distribution in tropical nd temperate waters. They occur off central and northern California rimarily during summer months and at times are very common both shore and offshore.

On August 21, 1960 while Department of Fish and Game personnel ere interviewing skindivers in the Pacific Grove area, several reported rge numbers of dead molas. The fish had been observed on the bottom depths of 30 to 50 feet, particularly off Cannery Row, Monterey.

Three weeks later, on September 9 and 10, the author observed veral molas floating ventral side up in the kelp off Lovers Point, acific Grove and off Cannery Row. All appeared to be dead. A fisher- an who had snagged a carcass said it weighed about 10 pounds and as in good condition except that the eyes were missing. Skindivers gain reported seeing dead and dying molas off Cannery Row during is period. The number reported by the various divers ranged from 2 to 30. All were approximately 18 to 24 inches long.

Skindivers did not report any dead molas off Cannery Row during ie weekend of September 24 and 25, but three were seen off Lovers oint and two off Point Pinos, Pacific Grove. All were floating on the rface and those observed off Point Pinos were lacking dorsal and al fins. No comments were received on the condition of the carcasses en off of Lovers Point.

A group of skindivers using SCUBA off Cannery Row on October 2, ported a few dead and dying molas, near where they were first re- orted in August. Some of these fish had large portions missing from ie ventral and dorsal regions. All appeared to be about the same size s was previously observed. On the same day, the author observed a ery weak mola a few yards offshore near Lovers Point. It was lying n its side with its ventral surface protruding slightly above the water, iggesting that it was near death and had lost its equilibrium.

Another heavy die-off evidently occurred later in the month. On October 22, the author observed an estimated 20 to 25 molas floating n the surface a few yards off of the rocky shore. In one small area ust north of Hopkins Marine Station, there were about 10 individuals. hese appeared to be lifeless when observed through 8x40 binoculars nd all had a portion of the ventral region protruding above the sur- ace of the water.

[1]Submitted for publication January 1961.

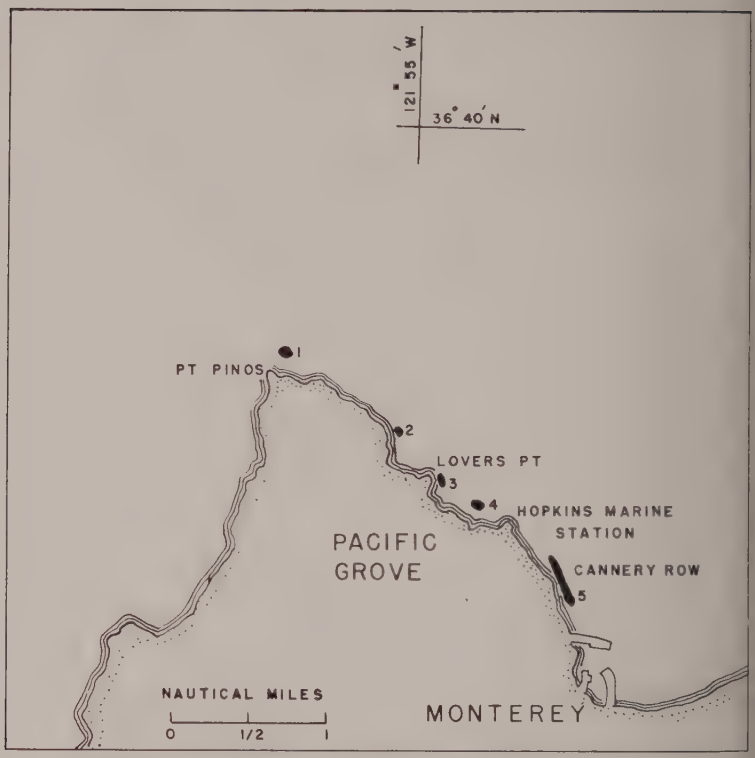

FIGURE 1. Location and quantity of dead molas in Monterey Bay during 1960

Date	*Area*	*Number of Molas Observed or Reported*
August 21	5	several
September 9, 10	5	up to 30
September 9, 10	3	several
September 25	1	2
September 25	2	3
October 2	3	1
October 2	5	few
October 22	5	up to 100
October 22	4	10
October 23	5	1
October 25	1	up to 12

On this same date, skindivers using SCUBA reported seeing an estimated 100 carcasses in about 50 feet of water off Cannery Row. On the following day (October 23) skindivers working in 30 feet of water, in this same area, found only one carcass. This specimen measured 48 cm. (19 inches) from the tip of the snout to the tip of the tail. The anal and dorsal fins and eyes were missing. The same day, skindivers reported seeing 5 to 10 dead molas on the bottom and one or two on the

urface off Pt. Pinos.[2] All were of approximately the same size as those reviously reported and most were missing dorsal and anal fins. On)ctober 29, a diver reported seeing five badly decomposed mola carasses off Cannery Row. This same diver stated he had observed a sea ion throwing a mola about in this area a few days earlier. It appeared o be alive at the time but one fin was missing. From this, one might nfer that some of the mutilation reported earlier could be attributed o sea lions; however, the missing eyes probably resulted from the feedng activities of gulls.

A question that arises in the author's mind is whether the penchant nolas have for floating at the surface on their sides is normal behavior r an indication of sickness and approaching death. Wales and Myers 1930) concluded that the molas observed offshore floating on their ides were "disabled" and that the natural position was upright. They)ased this conclusion on many observations of molas in waters around Hopkins Marine Station, Pacific Grove.

Fraser-Brunner (1951) believed the easily approached and captured nolas, "while 'basking' at the surface are in fact sick or dying fish", nd suggested that heavy infestation by parasites might be the cause for such disablement.

Other authors take the opposite view. Norman and Fraser (1938), stated that molas are fond of basking in the sun at the surface during calm weather, lying on their sides, with the dorsal fin protruding from the water.

Further underwater observations, such as those disclosing the Monterey Bay die-off, may help answer this and other questions pertaining to the habits of fishes.

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[2] One of the divers reported observing a similar die-off in October or November 1959.

HISTORY OF YEARLING KING SALMON MARKED AND RELEASED AT NIMBUS HATCHERY[1]

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INTRODUCTION

A release of marked king salmon yearlings was made into the American River in 1957 to determine the effectiveness of rearing the fish to this age at Nimbus Hatchery. At Nimbus most of the king salmon are released at an age of about 90 days. The fish selected for the experiment were from eggs taken in late December 1955 from American River stock at the hatchery. Late running fish were used because the waters at Nimbus have been too warm for rearing salmon until well into November. It was anticipated that the progeny of late running salmon would return in the season when the water temperatures at Nimbus were more favorable for salmon reproduction.

MARKING AND PLANTING

In January and February 1957 a total of 20,579 king salmon yearlings averaging 8.1 fish per pound were marked. The smallest fish in the lot weighed 10.6 per pound and the largest 6.8 per pound. Starting on March 7 and ending on April 8, 1957, seventeen separate releases of slightly over 1,000 fish each were made. All of the fish were planted in the American River at the hatchery.

The number of eggs used to produce the 20,579 marked yearlings was estimated to be approximately 50,000. This is slightly less than the average egg production of nine female salmon. Assuming a ratio of three males for every two females,[2] these 50,000 eggs would represent the offspring of 13 males (including jacks), or, 22 fish of both sexes.

Each fish was marked by excising the adipose and left ventral fins. This mark was assigned by the Pacific Marine Fisheries Commission for this experiment.

OCEAN RECOVERY OF MARKED SALMON[3]

Commercial Catch

In 1958, the year following planting, nine marked fish from the Nimbus release were found in that portion of the ocean troll catch which was sampled by Department of Fish and Game employees. In 1959 two marked fish were observed. Although the ocean sampling program covers all commercial salmon landings from Crescent City to Avila

[1] Submitted for publication, April 1961.
[2] In this experiment the sex ratio of the marked fish returning to the American River was estimated to be 1.46 males per female. See Table 4.
[3] Data supplied by Paul Jensen, Marine Resources Branch.

(San Luis Obispo County), Nimbus marked fish were recovered only at Bodega Bay and Point Reyes. For the purposes of the sampling program these locations are included in the San Francisco port area.

The adipose left ventral fin mark used for the Nimbus fish was also used in the Columbia River and Puget Sound areas. An examination of the scales of marked fish recovered off Oregon and Washington indicates that none which were taken there were from Nimbus; conversely, examination of the California recoveries indicates that they were all from Nimbus. Separation of the northern from the Nimbus fish was simplified by the difference in their early life history. The Nimbus fish were held in the hatchery for over a year; the others for a much shorter time.

TABLE 1

Recovery of Marked King Salmon From Nimbus Hatchery in Commercial Landings [1]

Year	Month	Number marks recovered	King salmon examined during month	King salmon landed during month	Calculated number marks landed during month
1958	May	1	5,909	56,305	10
	June	5	6,240	50,292	40
	July	1	5,609	44,925	8
	August	1	504	6,454	13
	September	1	883	4,206	2
Total		9			73
1959	July	1	22,390	168,868	8
	August	1	9,245	61,441	7
Total		2			15

[1] All recoveries were taken in the San Francisco area although catches were sampled throughout California, Oregon, and Washington.

Since only a portion of the troll catch was sampled, the numbers of marked fish were weighted up to the numbers which should theoretically have appeared in the entire catch (Table 1). Thus, it is estimated that in 1958 a total of 73 marked fish was taken by commercial fishermen and an additional 15 in 1959. None were taken in 1960.

The average weight of the marked salmon sampled in 1958 was 7.2 pounds dressed, head on. Assuming the same average weight for the 73 fish taken in the fishery, the total weight of marked fish would be 526 pounds. At an average price of $0.35 per pound, the salmon had a net worth to the fishermen of $184.10. The fifteen marked salmon in the 1959 catch had an estimated average weight of 15.5 pounds each, or a total weight of 232 pounds. At the average price of $0.50 per pound which prevailed during this season, these marked salmon were worth $116 to the fishermen. Combining the value of the marked, commercially-caught fish for 1958 and 1959, we find that it is approximately $300.

Sport Fishery

The ocean sport fishery was not sampled but verbal reports were received of marked fish appearing in the catch, and two such fish were turned in by San Francisco party boats. Pelgen (1955) has calculated

he value of sport caught salmon to be about $17 per fish. The total alue of the marked salmon to the sport fishery is unknown but $34 epresents a minimum figure.

RETURNS TO HATCHERY

The first returns of the marked fish to Nimbus Hatchery occurred in he fall and winter of 1957-58 (the year of release). One hundred

TABLE 2

Weekly Returns to Nimbus Hatchery of Marked King Salmon

		In holding ponds			
		Male	Female	Monthly totals	Annual totals
957-58	Oct. 13 to Oct. 19	1			
	Oct. 20 to Oct. 26	1			
	Oct. 27 to Nov. 2	7		9	
	Nov. 3 to Nov. 9	11			
	Nov. 10 to Nov. 16	14			
	Nov. 17 to Nov. 23	22			
	Nov. 24 to Nov. 30	12		59	
	Dec. 1 to Dec. 7	16			
	Dec. 8 to Dec. 14	6			
	Dec. 15 to Dec. 21	10			
	Dec. 22 to Dec. 28	1			
	Dec. 29 to Jan. 4	1		34	102
1958-59	Oct. 26 to Nov. 1	1	3	4	
	Nov. 2 to Nov. 8	1			
	Nov. 9 to Nov. 15	2	18		
	Nov. 16 to Nov. 22	17	28		
	Nov. 23 to Nov. 29	19	54	139	
	Nov. 30 to Dec. 6	35	79		
	Dec. 7 to Dec. 13	14	17		
	Dec. 14 to Dec. 20	6	13		
	Dec. 21 to Dec. 27	9	6		
	Dec. 28 to Jan. 3	5	5	189	
	Jan. 4 to Jan. 10	2	1		
	Jan. 11 to Jan. 17		1	4	336
1959-60	Sep. 27 to Oct. 3	2			
	Oct. 18 to Oct. 24	1			
	Oct. 25 to Oct. 31	1		4	
	Nov. 1 to Nov. 7	1	3		
	Nov. 8 to Nov. 14		1		
	Nov. 15 to Nov. 21	6	13		
	Nov. 22 to Nov. 28		6	30	
	Nov. 29 to Dec. 5	1	6		
	Dec. 6 to Dec. 12		5		
	Dec. 13 to Dec. 19		3		
	Dec. 20 to Dec. 26	2	1		
	Dec. 27 to Jan. 2		1	19	
	Jan. 3 to Jan. 9	1		1	54

and two marked grilse were recovered. All were males. These fish had an average fork length of 35 centimeters.

During the following season, 1958-59, an even more spectacular showing was made with the return of 336 marked fish to the hatchery. Of these three-year-old fish, 111 were males and 225 were females. In addition, 21 male salmon under 66 centimeters in length were recovered from the upstream face of the Nimbus fish rack. Had the rack structure been a completely effective barrier, these fish presumably would have entered the hatchery.

Marked salmon continued to return to Nimbus in the 1959-60 season although in smaller numbers than in the preceding year. Fifty-four

TABLE 3

Marked Salmon Recovered in American River

1957-58 Season			1958-59 Season		
Recovery date	Sex	Length (cm.)	Recovery date	Sex	Length (cm.)
1957 Nov. 25	M	35	1958 Dec. 4	M	No data
25	M	38	4	F	No data
25	M	39	16	F	61
25	M	39	23	F	59
25	M	40	23	F	68
25	M	40.5	23	F	70
Dec 3	M	36	1959 Jan. 2	F	77
3	M	39	2	F	75
3	M	40			
3	M	40.5			
3	M	40.5			
3	M	41.2			
3	M	41.6			
3	M	42			
3	M	42			
3	M	42			
3	M	44			
3	M	45			
3	M	48			
4	M	39.5			
4	M	39.5			
4	M	41			
9	M	35			
9	M	37			
9	M	37.2			
9	M	38			
9	M	38			
9	M	38.5			
9	M	39			
9	M	40			
9	M	41			
9	M	43			
9	M	43			
9	M	44			
9	M	44			
10	M	36			
10	M	36			
10	M	39			
10	M	42.5			
10	M	44			
19	M	40.5			
19	M	45			
19	M	45			
27	M	46.5			

1959-60 Season		
Recovery date	Sex	Length (cm
1959 Dec. 17	F	59
18	M	48

ere recovered—15 males and 39 females. A single marked female as removed from the fish rack.

During 1957 sixty-seven percent of the marked grilse or jacks entered ie hatchery after November 15 when water temperatures were favorble for salmon reproduction. This figure is not particularly significant nce jacks are seldom used in a hatchery operation. However, it is gnificant that in 1958 ninety-two percent of the marked fish arrived t Nimbus after the period of critical water temperatures, and eighty-iree percent in 1959. This would indicate that the time of migration s an inherited characteristic; i.e., the progeny of a late-running strain ontinue to run late. Detailed information on time of arrival of marked sh at Nimbus Hatchery is presented in Table 2.

RIVER RECOVERY OF MARKED SALMON

As would be expected, some of the marked fish spawned in the American River downstream from Nimbus Hatchery. The salmon surrey crews recovered 44 carcasses of marked fish in 1957, eight in 1958, nd two in 1959. With the exception of six carcasses which were taken n Nov. 25, 1957, all other marked fish were recovered in December nd early January. See Table 3. On the basis of tag and recovery experiments performed in earlier years, it was estimated by the survey crews that water conditions in each of the three years were such that hey recovered about 25 percent of the salmon actually in the river below Nimbus racks. It was estimated that they recovered about 92 percent of the fish which got above the racks. On the basis of these assumptions it is estimated that the total return to the river, including he hatchery, was 278 fish in 1957, 391 in 1958, and 63 in 1959. Of hese 732 fish it is estimated that 435 were males and 297 females. For letails see Table 4.

EGG PRODUCTION OF RETURNING MARKED FISH

Of the 264 marked female salmon returning to Nimbus Hatchery in the 1958-59 and 1959-60 seasons, 179 were spawned artificially. The average number of eggs produced per marked female was 5,700 and the total take from these fish amounted to 1,020,300 eggs. This represents a return of about 20 eggs for every one expended.

An abnormally high mortality of 32 percent in the holding ponds reduced the 264 females which entered the hatchery to the 179 which were spawned. Practically all the marked fish were very "green" on arrival and had to be held an unusually long time before their eggs ripened.

For the purpose of determining the number of eggs that marked salmon deposited in the spawning riffles of the American River, it was calculated that there were 28 large females in the 1958 run and five in 1959 for a total of 33. Multiplying this figure by 5,700 (the average number of eggs per marked female spawned at the hatchery), it is estimated that 188,100 were produced by this segment of the marked salmon population. When this egg production is added to the number taken at the hatchery, we find that an estimated 1,208,400 eggs were produced by the marked fish which returned to the American River to spawn.

TABLE 4

Recoveries and Estimated Total Returns to American River

	Numbers recovered			Estimated total returns			
				Numbers			Percent total
	Male	Female	Total	Male	Female	Total	
1957							
Entered hatchery	102	0	102	102	0	102	13.7
On or above Nimbus racks	0	0	0	0	0	0	0
American River downstream from racks	44	0	44	176	0	176	24.3
Total 1957	146	0	146	278	0	278	38.0
1958							
Entered hatchery	111	225	336	111	225	336	45.9
On or above Nimbus racks	21	0	21	23	0	23	3.1
American River downstream from racks	1	7	8	4	28	32	4.4
Total 1958	133	232	365	138	253	391	53.4
1959							
Entered hatchery	15	39	54	15	39	54	7.4
On or above Nimbus racks	0	1	1	0	1	1	0.1
American River downstream from racks	1	1	2	4	4	8	1.1
Total 1959	16	41	57	19	44	63	8.6
Three year total	295	273	568	435	297	732	100.0

TABLE 5

Summary of Recoveries of Marked Nimbus Salmon
1957-1960

Source	Actual recoveries	Weighted recoveries	Percent recovery (weighted)
Commercial ocean troll fishery*	11	88	0.427
Ocean sport fishery	2	2	0.009
Nimbus Hatchery	492	492	2.390
Nimbus fish rack	22	24	0.116
American River below rack	54	216	1.049
Total		822	3.991

* All taken in 1958 and 1959.

TABULATION OF MARKED FISH RECOVERIES FROM ALL SOURCES

Since there is no information available on the number of marked salmon taken in the ocean sport fishery or in the sport fishery in inland waters, any tabulation of marked fish returns will be a minimum figure. In Table 5 all available recovery data are summarized, showing that we can account for approximately 4 percent of the marked fish released.

COST AND VALUE OF REARING KING SALMON TO YEARLING SIZE

The cost of rearing the 20,579 king salmon yearlings used in this experiment was abnormally high because of the special treatment made necessary by the high water temperatures at Nimbus Hatchery. The Department expects to have an adequate supply of cool water in the future; hence the cost of rearing this particular group of fish would have no bearing whatsoever on the cost of rearing others in years to come.

To estimate the cost of rearing a similar number and size of fish under the more nearly normal conditions which should prevail in the future, we propose to use the average cost per pound of rearing catchable and subcatchable trout. In 1958 the average cost of rearing such fish for all hatcheries of California was 72¢ per pound.[4] The cost of raising fish in the larger, lowland hatcheries of which Nimbus would be a fairly typical example was less than the State average, but to be on the safe side we propose to use the average figure of 72¢. The 20,579 yearling salmon averaged 8.1 fish per pound and weighed a total of 2,540 pounds. At 72¢ per pound this represents a total cost of approximately $1,830. As discussed above, this group of fish is known to have produced a commercial catch worth approximately $300 and a sport catch with a minimum value of $34. It is quite probable that the actual value of the sport catch considerably exceeded the $34 minimum figure, but it is highly doubtful that the combined commercial plus sport values even approached the cost of production of these fish. In other words, rearing salmon to yearling size would be a prohibitively expensive way of providing fish for the sport and commercial fisheries. On the other hand, if future experiments prove that the hatchery returns obtained thus far are at all typical, it would seem that using this method might be a satisfactory and cheap method of building up the run of king salmon in a stream which has been badly depleted by over-fishing, pollution, or some natural disaster.

Calculated on the basis of the cost to produce a spawning fish returned to the hatchery or to the American River, the average cost of the 732 returning spawners was $2.50 per fish; if we deduct all jacks (two-year-olds) the cost goes up to $4.03. The abnormally high mortality of 32 percent which occurred among females in the hatchery holding ponds at the time of the experiment is no longer a problem and is not likely to recur after the temperatures of the hatchery water supply are reduced to a more nearly optimum level. Even assuming that these mortalities did recur at the previous rate, the average cost of surviving adults would be only $5.97. This is still a very low cost for a fish whose progeny would normally be expected to contribute three or four fish to the commercial plus sport fisheries every three or four years. The cost is especially low if it is used (as it should be) only in streams where spawners are in short supply.

Various salmon marking experiments have indicated that for king salmon a reasonably healthy condition exists when the sport and commercial fisheries take three or four salmon for every one that returns to spawn. (The ideal ratio varies from stream to stream.) In this experiment, there were more than eight spawners for every fish taken

[4] California Trout Production and Costs 1957-1958 by Macklin and Tharratt. Inland Fisheries Administrative Report No. 58-15.

by the commercial fishery. The sport fishery was not properly sampled but typically the sport catch is much smaller than the commercial catch. Even if the sport catch of this particular group equalled the commercial catch, it would mean that more than four fish escaped to spawn for every one that was caught. In other words, of those fish that were either caught or escaped to spawn, it appears that something well in excess of 80 percent escaped to spawn instead of the more usual 20 to 25 percent.

Considerably more impressive than the ratio between fish caught and fish which escaped to spawn is the percentage of the fish planted which either returned to the hatchery or spawned naturally in the American River. This amounted to a total of 732 fish, or 3.56 percent of the total number planted. Of these fish, 492 were taken at the hatchery—this is 2.39 percent of those released. A comparison was made with returns from 47 lots of fall run kings released by the California Department of Fish and Game, the U. S. Fish and Wildlife Service, and the Washington State Department of Fisheries.

Thirty-four of the forty-seven lots of marked fish were released as "fingerlings" or "spring releases". Ninety days is a common age of release for such fish. It is possible that some groups of "fingerlings" may have been held until summer. The three highest rates of return were made under conditions which were not comparable with the others.[5] Of the other thirty-one groups the rate of return[6] ranged from 0.000 to 0.471 percent, and the mean was 0.070 percent.

Two groups of fish definitely were released in their first summer. The returns were 0.002 and 0.009 percent.

Nine groups were held until fall. Their rates of return ranged from 0.002 to 0.432 percent; the mean was 0.164 percent. Four of these fall releases are described in detail by Cope and Slater (1957). In each of four years a part of the fall run kings was marked and released as fingerlings in the spring, and a roughly equal part was held until fall. Mortality during the summer somewhat reduced the numbers released in the fall. The commercial gill net fishery was sampled to determine which group contributed most. To quote from Cope and Slaters' summary: "Comparisons of returns to the gill-net fishery and to Coleman Hatchery of adult marked salmon from both spring and fall releases indicated that fish from spring releases averaged larger than those from fall releases, but that somewhat more fish were recovered from fall releases than from spring. The greater return of fall-released fish was more marked at Coleman Hatchery than in the commercial fishery. Thus, spring-released fish contributed the greater weight to the gill-net fishery, while fall-released fish contributed the greater weight to the Coleman Hatchery returns".

We could find records of only two usable groups of fall run kings which were released as yearlings. The rates of return were 0.072 and

[5] These three experiments were done on the Deschutes River in Washington. Formerly this river had no salmon runs because of an impassable waterfall near its mouth in Puget Sound. A fishway was built around the falls. The salmon were planted near salt water. The total returns to the stream were 0.98 percent, 0.95 percent, and 0.68 percent (as compared with 3.56 percent in the American River).

[6] The rate of return could not be measured in the same way for each release. When available the figure used is based on fish which actually entered the hatchery. In some instances the count included all marked fish which passed through a counting station on their way to the spawning grounds or the hatchery.

0.073 percent, which is not appreciably better than the mean rate of return for fingerlings.

Besides the experiments involving fall run kings we found records of more than twenty releases of spring run kings, most of which were yearlings. These spring run yearlings were released by the Oregon Game Commission in the Umpqua and Rogue Rivers. The Rogue River experiments involved the release of sixteen groups. The mean rate of return was 0.797 percent. The highest was in the range of 3.5 to 3.7 percent (some marks had regenerated and could not be assigned to the proper group with certainty). The poorest return was 0.000 percent. Various factors which could have affected the rate of return are discussed in the 1959 report of the Oregon State Game Commission, Fishery Division. The average size of the fish in the different groups varied from less than ten to about thirty fish per pound. The fish which were reared to the larger sizes showed the best returns.

Only one Umpqua release was written up in such a manner that the data could be used in this comparison. About 1.5 percent of these fish were taken in the commercial troll fishery, 0.2 percent in the river sport fishery, and 3.4 percent escaped to spawn.

The Umpqua and Rogue River returns included all spawning fish which escaped the fisheries at the river mouths; i.e., these returns corresponded to the 2.39 percent which returned to Nimbus Hatchery plus the 1.17 percent which spawned naturally in the American River (total 3.56 percent).

Only two groups of spring run kings were found which were released as fingerlings in their first spring. The returns were 0.000 percent and 0.046 percent. Another two groups were released in their first fall. The returns were 0.007 and 0.049 percent.

The marking experiments discussed above do not demonstrate that there is or is not a difference between the rate of return of spring run and fall run king salmon released at the same age. There were 31 groups of fall run fingerlings and only two groups of spring run fingerlings. There were nine groups of fall run fall releases and only two groups of spring run fall releases. Finally, there were two groups of fall run yearlings and seventeen groups of spring run yearlings. For details see Table 6.

These marking experiments were performed by four different organizations in many different places for many different purposes over a 33-year period. Conditions which seriously affected survival rates in some experiments were lacking in others. The methods of recovery differed from place to place. These things and others tended to give greater variation in the rate of return than would be expected in a set of controlled releases made as part of a single experiment.

If we assume that the age at release has more influence on the rate of return than any difference between spring run and fall run fish, then we must conclude that on the average a much higher rate of return can be expected if the fish are released as yearlings. The return of the Nimbus fish (fall run) was about the same as the best returns of the groups of spring run yearlings, and was far better than any return of fall run kings—including the two groups of yearlings. It would appear that further experimenting with fall run yearlings could be expected to produce high rates of return. We cannot predict the

TABLE 6

Returns From King Salmon Marking Experiments

	Number of experiments	Percent return[1]		
		Max.	Min.	Mean
Fall run king salmon				
Released in their first spring (often at about 90 days' age)	31[2]	0.471	0.000	0.070
Released in their first summer	2	0.009	0.002	0.006
Released in their first fall	9	0.432	0.002	0.164
Released as yearlings	2	0.073	0.072	0.072
Spring run king salmon				
Released in their first spring	2	0.046	0.000	0.023
Released in their first fall	2	0.049	0.007	0.028
Released as yearlings	17	3.6±	0.000	0.950

[1] As used here, the term "return" could not be given the same meaning for each release. In some experiments the term included only those fish which were actually retaken at the hatchery. In other instances it included a count of all marked fish passing through a counting station on their way to the spawning grounds, etc.

[2] These experiments do not include three releases made in the Deschutes River, Washington, which had spectacularly high returns under conditions which were entirely atypical (see text for details). Also excluded are several experiments which were so performed as to greatly reduce the chance of any hatchery returns.

consistency of these returns. Unfortunately the cost of rearing yearlings is high, but not so high as to make experimenting impractical.

DISCUSSION

It is difficult to draw conclusions from a single salmon marking experiment involving only a relatively small number of fish. However, the evidence obtained from the release of some 20,000 marked yearling salmon at Nimbus Hatchery cannot be ignored.

The returns of the Nimbus experiment were compared with those of 65 other releases of marked king salmon. The proportion which returned to spawn was found to be several times as high as that of any group which was released when appreciably less than a year old. The only groups with roughly comparable rates of return were of spring run yearlings released in Oregon. In Oregon and Washington most spring run king salmon migrate to the ocean as yearlings, so holding them in the hatchery would not upset their normal migration pattern. Fall run kings normally migrate to sea as fingerlings, but the Nimbus experiment would seem to indicate that holding them in the hatchery will increase their chances of survival. By way of contrast, the only other releases of fall run yearlings (two releases made in the Pacific Northwest) showed returns which were about the same as the average return for fingerlings. More experiments will be needed to determine if the Nimbus results can be duplicated.

If these first Nimbus returns are typical and if additional spawners are needed it would appear desirable to hold some fall run kings until they are yearlings.

If a net gain of over a million eggs in the hatchery and in the natural spawning beds can be achieved by a release of 20,000 yearling salmon produced from 50,000 eggs, it would appear that spawning runs could

be built up rapidly by releasing several hundred thousand yearlings for a period of a few years.

On the other hand, the data show that the group of marked fish made a rather minor contribution to the commercial fishery. There are probably several reasons for this, one of which is that over 53 percent of the marked fish matured in their third year and less than 9 percent in their fourth.[7] As a result of this unusually high percent of three-year-old spawners, the fish were available to the commercial fishermen for only a short period of time. Contributing to this same lessening of availability was the long stay in fresh water. This results in slower growth and a smaller average size at maturity. It is probable that the marked fish did not reach the 26-inch commercial size limit until later than others of the same year class.

It is unfortunate that there was no program to sample the ocean sport catch. With a 22-inch size limit on sport caught salmon, it is probable that the marked salmon made a relatively more substantial contribution to the sports fishery than they did to the commercial catch. Normally the commercial catch of kings is several times the sport catch; in this instance the ratio is of course unknown.

Marking experiments show variable rates of survival from year to year, but if yearling kings consistently do show a reasonably high rate of return, the method should be valuable in enabling hatchery men to build up the run in a stream without going elsewhere for a source of eggs. The "robbing Peter to pay Paul" method of taking eggs from one stream for planting in another is all too apt to damage Peter without benefiting Paul.

SUMMARY

1. A total of 20,579 yearling king salmon from a late-running strain was marked and released at Nimbus Hatchery in the spring of 1957. About 50,000 eggs were used to produce these fish; this represents the egg production of about nine females, or, 22 fish of both sexes.
2. Based on marked fish recoveries in the portion of the ocean troll catch sampled by Department of Fish and Game personnel, it is calculated that 88 marked salmon from the Nimbus plant were taken by the troll fishery in 1958 and 1959. These fish had a value of approximately $300 to the fishermen.
3. There is evidence that marked fish from Nimbus were taken in the ocean sport fishery, but no sampling was done and no estimate could be made of numbers. Two marked fish were returned by sport fishermen; these represented a value of $34.
4. A total of 492 marked fish returned to the hatchery. Of these, 102 were two-year-old jacks, 336 were three-year-old fish, and 54 were four years of age. In addition, an estimated 24 marked fish died above the Nimbus fish racks.

[7] Over most of the Pacific coast, four-year-old spawners are the most common. This used to be true throughout California, but there are indications that in the Sacramento the proportion of three-year-old spawners has been increasing and may now exceed the four-year-olds, but not by any such proportion as that given above.

5. Marked females were nearly all green on arrival at the hatchery and had to be held an unusually long time before spawning. A mortality of 32 percent occurred during this period.
6. Most of the marked fish returned to the hatchery in late November and December, indicating that progeny from a late-running strain of salmon tended to retain the late-running characteristic.
7. A total of 1,020,300 eggs was taken from marked fish returning to Nimbus Hatchery. This represented a net gain of more than 900,000 eggs over the number of eggs required to produce the group of fish which was marked.
8. It is estimated that 216 marked salmon spawned in the American River. Of these, it is calculated that 33 were females which produced 188,100 eggs.
9. About 4 percent of marked yearling salmon released at Nimbus Hatchery can be accounted for in the ocean catch and in the spawning runs in the American River.
10. High temperatures at Nimbus Hatchery resulted in an abnormally high rearing cost for the fish used in this experiment. The Department expects to have a cooler water supply in the future.
11. Based on the 1958 average rearing cost of catchable and sub-catchable trout, the future cost of rearing a similar group of salmon would be about $1,830 as compared with the $300 value of the commerical catch from this group and the minimum sport catch value of $34.
12. The cost of producing a spawner (at 1958 rearing costs) would be about $2.50 per fish, or $4.03 if two-year-old spawners are excluded.
13. A healthy king salmon fishery often supports a catch-to-escapement-ratio at least as high as three or four to one; in this experiment the ratio was less than one-fourth to one.
14. The yearling salmon which returned to the hatchery were 2.39 percent of the total number released; an additional 1.17 percent spawned naturally; thus the total spawning escapment was 3.56 percent.
15. Nimbus Hatchery returns were compared with the hatchery returns of 65 other releases of marked king salmon. Thirty-one of these groups were of fall run fingerlings released in their first spring. Nine groups of fall run fish were released in their first fall. The average rates of return were 0.070 and 0.164 percent respectively. Seventeen groups were of *spring run* yearlings. The average rate of total spawning escapement was 0.95 percent and the maximum was about 3.6 percent. There were eight other groups of fish which did not fit any of the above classifications.
16. If future experiments show similar rates of return, the release of yearling kings might prove to be an effective way of building up a depleted run.

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BRUSH MANAGEMENT IN RELATION TO FIRE AND OTHER ENVIRONMENTAL FACTORS ON THE TEHAMA DEER WINTER RANGE[1]

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INTRODUCTION

The studies reported here were started on the Tehama deer winter range in the summer of 1948 and were continued until the spring of 1960. The primary objective was to study browse conditions—particularly brush seedling establishment and growth—with the idea that certain environmental factors might be manipulated to improve deer ranges. Fire was the principal factor studied, but attention was given to the importance of soils, competition of herbaceous vegetation with the brush seedlings, deer browsing, and weather.

In September of 1947 an intense wildfire burned several thousand acres in the middle of the deer winter range, killing the aerial portions of nearly all the shrubs. On July 7, 1948, plots were located along a 6-mile strip between Mill Creek and Antelope Creek, on both burned and unburned portions. Data were taken from these plots.

The Tehama deer winter range is utilized by Columbian black-tailed deer (*Odocoileus hemionus columbianus* [Richardson]). These deer are migratory, summering in and about Lassen Volcanic National Park, and wintering along the foothill slopes bounded by the watersheds of Battle Creek on the north and Deer Creek on the south. Deer usually move from the summer to the winter range in the middle of October. Once they reach the winter range they disperse over the area and remain approximately 210 days. By the first week in May they have generally started their return to the summer range. No deer remained during the summer in the area where the plots were located.

The fall migration is well known to sportsmen, who concentrate much of their hunting effort there from the middle to the end of October. Heavy hunting also occurs after the deer have settled on their winter range. While the Tehama deer winter range is regarded as an excellent area for both deer and hunters, the brush stand could be improved in some places.

DESCRIPTION OF THE TEHAMA DEER WINTER RANGE

The Tehama deer winter range consists of over 220,000 acres. The State of California owns 42,897 acres of this range which is managed

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by the California Department of Fish and Game. It lies in the western foothills of the Sierra Nevada in Tehama County, between elevations of about 800 and 3,000 feet. Geologically, the area is of volcanic origin, having been influenced by a series of mud flows attributable to the volcanism of the Lassen Park region to the northeast. Steep-sided canyons with exposed, prominent rim rocks and lava outcroppings characterize the area.

During the period of study, no livestock grazed around the study plots; therefore cattle had no effect on the browse plants being investigated. A few rabbits, California ground squirrels, kangaroo rats, and pocket gophers are on the range. Grasshoppers were abundant during some years.

Vegetation

The general aspect is woodland-grass of the Upper Sonoran life-zone. On the lower portion of the area, blue oak (*Quercus douglasii*) and wedgeleaf ceanothus (*Ceanothus cuneatus*) are the dominant woody species (Figure 1). The shrubs and trees increase in abundance at higher elevations, and here the principal species are wedgeleaf ceanothus, California scrub oak (*Q. dumosa*) scrub interior liveoak (*Q. wislizenii,* var. *frutescens*), western mountain mahogany (*Cercocarpus betuloides*), and two non-sprouting manzanitas, whiteleaf and common, (*Arctostaphylos viscida* and *A. manzanita*). Scattered about are a few other species of less importance, such as yerba santa (*Eriodictyon californicum*), Fremont silktassel (*Garrya fremontii*), western hop-tree (*Ptelea baldwinii*), chaparral honeysuckle (*Lonicera interrupta*), California juniper (*Juniperus californica*), California laurel

FIGURE 1. Woodland-grass vegetation in the lower elevations of the Tehama deer winter range. During fall, deer eat acorns and dry leaves of the blue oak.

(*Umbellularia californica*), redbud (*Cercis occidentalis*), and pitcher sage (*Sphacele calycina*).

At the upper portion of the range, above the plot locations, other browse species occur, such as deerbrush (*Ceanothus integerrimus*) and squaw carpet (*C. prostratus*). For the entire winter range, woody species cover about 17.5 percent of the surface area, and are distributed in a striated fashion as shown in Figures 2 and 3. Woody species are

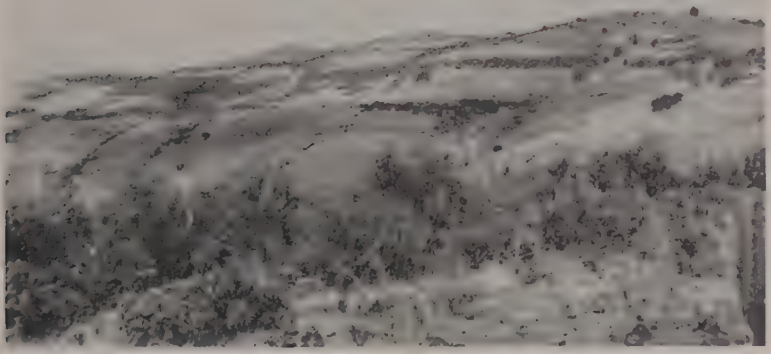

FIGURE 2. Distribution of shrubs on a south-facing exposure, determined chiefly by the underlying soil.

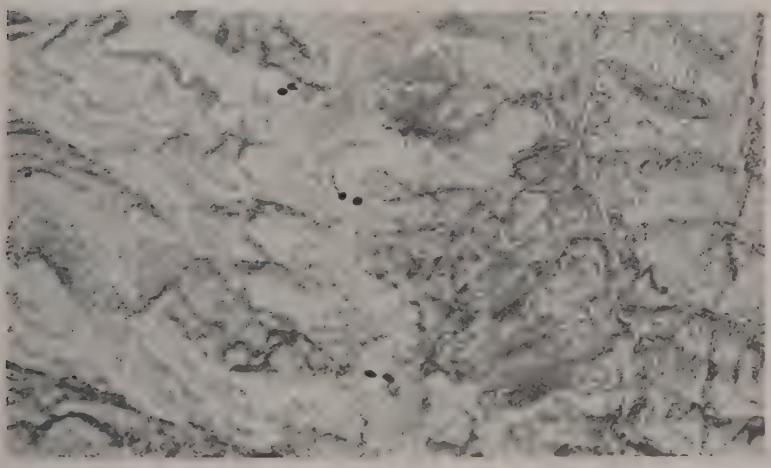

FIGURE 3. Aerial photo of Tehama deer winter range. Note the striated distribution of the woody species. Black dots are locations of study plots 1 to 6.

most abundant on the north exposures where they often form rather dense chaparral over areas several acres in extent (Figure 4).

The herbaceous vegetation consists chiefly of annuals, both grasses and forbs. Together they cover about 27.2 percent of the soil surface. The grasses consist mostly of soft chess (*Bromus mollis*), foxtail fescue (*Festuca megalura*), red brome (*B. rubens*), ripgut brome (*B. rigidus*), slender wildoat (*Avena barbata*), California melic (*Melica californica*), and malpais bluegrass (*Poa scabrella*). Principal forbs are redstem filaree (*Erodium cicutarium*), Napa thistle (*Centaurea melitensis*), clovers (*Trifolium* spp.), hairy lotus (*Lotus subpinnatus*), and godetia (*Godetia dudleyana*).

Perennial grasses account for only 0.5 percent of the range, and 54.8 percent is composed of nonproductive rocks and bare soil. (All composition figures are from Leach and Hiehle, 1957).

Both the grasses and forbs are species found abundantly throughout most of California's annual plant vegetation. These species germinate with the advent of fall rains, grow rather rapidly for a while, then slow down until, in late December, January, and early February, they grow very little. Rapid growth starts again in late February, and by May 1 the annuals are mainly dry. As with most of California's ranges, the annual vegetation is quite variable from year to year, both in species composition and amount of forage on the ground at any given time (Talbot *et al.*, 1939). The amount of growth is determined largely by combinations of precipitation and temperatures. Although the range does not have high grazing capacity for livestock, the forage is nutritious and of good quality.

FIGURE 4. Typical brush cover on north exposures.

Soils

Two soil series are found over the Tehama winter range. The Toomes series predominates, and consists of well-drained lithosols developed from volcanic breccia composed of angular basic igneous rocks cemented together by tuffaceous sediments. These soils are found under the blue oak-grass and grass vegetation (Figure 1). Characteristically the Toomes soils are brown, shallow, slightly acid, and rocky. The soils on the ridge tops and high plains are 8 to 12 inches deep; on north facing slopes they may be 24 inches; but on some of the south facing slopes they are only 3 to 8 inches deep. In many places the soils are too shallow to support other than annual herbaceous vegetation.

The Stover soil series occur on ledges and concave slopes of a volcanic breccia where soil material has accumulated through creep of colluvial action in combination with the weathering of less resistant strata of the formation. These soils are brown, very slightly acid, with modern profile development. They range in depth from 30 inches to over 5 feet, but are predominantly 30 to 40 inches deep. This type of soil supports the scrub oak, scrub interior liveoak, and associated shrubby species. The striated character of the vegetation shown in Figures 1 and 2 is determined largely by the differences between the Toomes and Stover soils.

Climate

The climate is characteristic of the foothill region of California. The winters are generally quite mild, but with some freezing of soils, and the summers are hot. Precipitation records for the years of study are shown in Table 1. Although infrequent, heavy persistent snows do occur, and can be important as far as the deer are concerned. Snow sometimes covers the herbaceous forage, making it largely unavailable. Furthermore, snow storms can cause the deer to concentrate where food conditions are not favorable. For example, in the winter of 1948-49, heavy snow caused many deer to move down to the bank of Mill Creek where

TABLE 1

Precipitation Records for Red Bluff, California *
Precipitation (inches)

Season	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
1947-48	.02	4.77	1.15	1.97	2.06	.98	4.47	6.51	2.68	1.02	.13	.14
1948-49	.70	.53	.78	5.15	.39	1.77	8.33	.10	1.74	0	T	0
1949-50	T†	T	.94	.74	5.48	4.33	2.05	.33	.60	.21	0	.05
1950-51	.17	3.53	2.20	4.56	5.10	2.46	.12	.82	1.51	.10	0	.04
1951-52	.33	1.98	4.21	4.54	6.32	1.60	4.31	.74	.49	.95	.20	0
1952-53	.03	.10	2.21	10.09	3.56	.26	.55	4.24	1.29	1.13	0	.10
1953-54	0	.58	3.11	.46	3.55	3.00	4.07	1.24	.01	.83	T	1.23
1954-55	.15	.40	6.82	5.26	2.96	.09	.50	1.68	.18	.26	.08	0
1955-56	1.11	.38	3.63	7.71	8.63	1.09	.01	1.27	4.04	.58	T	0
1956-57	.29	.50	.08	T	3.56	1.92	2.61	1.61	1.67	.01	T	0
1957-58	2.47	4.30	1.20	2.59	5.50	11.38	5.57	2.47	1.49	1.06	.42	.07
1958-59	.21	.46	.13	1.10	5.86	4.08	.41	.39	.28	.05	T	.03
1959-60	1.03	.04	T	1.06	4.63	4.27	2.45	2.36	.48	T	T	0

* Precipitation on the Tehama winter deer range was probably somewhat greater than that at Red Bluff. Nevertheless, the records for Red Bluff indicate the distribution and amount of precipitation on the range.
† Trace.

many of them died. Normally, however, snows are light, and melt off rapidly.

FOOD HABITS OF DEER

Food habits of deer on the Tehama winter range were studied by the Game Management Branch of the California Department of Fish and Game, and the results were reported by Leach and Hiehle (1957). Their studies show the relative amounts of grasses, forbs and browse consumed, and the importance of acorns and dry oak leafage after the deer arrive on the range (Figure 5). Browse was found to be the most important food item in the winter, but in the spring the grasses and forbs comprised most of the forage. For the entire winter season, browse, including acorns and oak leafage, accounted for nearly 70 percent of the diet, and herbaceous vegetation for about 30 percent. The heavy use of herbaceous plants in March and April indicates the competition that exists between deer and livestock for forage on foothill ranges. On the first of May, deer fed heavily on the abundant new leaves of oaks, almost to the exclusion of other food.

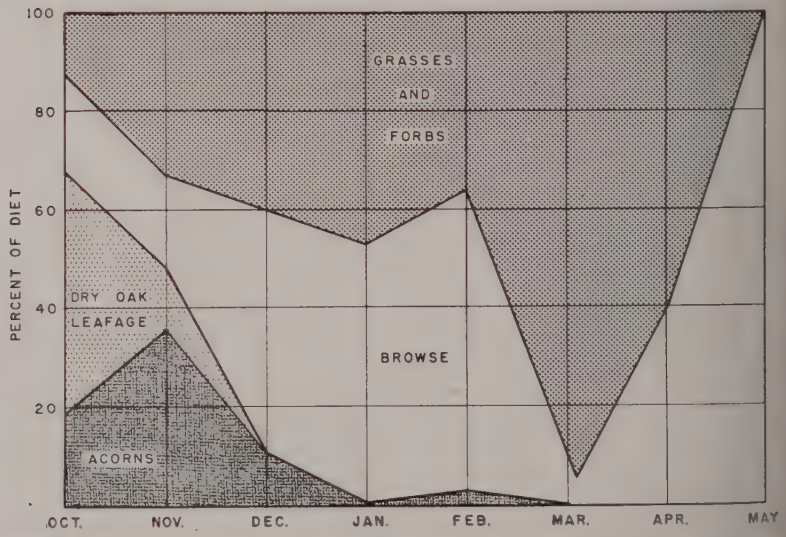

FIGURE 5. A graphic representation of foods eaten on the Tehama winter deer range. (Adapted from data by Leach and Hiehle, 1957.)

ECOLOGY OF BRUSH SPECIES

In managing brushlands for game, the operator, or game manager, must be able to identify each species and know its value as browse. Furthermore, he must know the ecology of each species: where it normally grows; whether or not it loses its leaves in the fall and is bare while deer are on the range; whether it reproduces only from seed or stump sprouts or both; its reaction to a single fire and to repeated burning; its ability to compete successfully with other vegetation; and its general resistance to browsing. With this information, the game man-

ager is able to manage his range efficiently, and to predict the success of any new management practice.

The following discussions are concerned only with species within the particular study areas.

Wedgeleaf Ceanothus

The most abundant and widely distributed shrub on the Tehama deer winter range is wedgeleaf ceanothus. On the Tehama range it grows to a height of 9 feet but averages about 6 feet. The leaves are smaller than in many other portions of its distribution range. Strains with larger leaves probably would be more desirable as deer browse. This shrub does not lose its leaves in winter, and is generally considered an excellent browse for deer on winter ranges. Sheep are also fond of this browse, but cattle eat it sparingly unless other forage is scarce. This species principally reproduces by seed except occasionally when a new plant arises by layering as a result of a limb's coming in contact with the soil, chiefly when protected from grazing.

Wedgeleaf ceanothus produces seed every year, but the crop is larger some years than others. The capsule dehisces upon opening, and the seeds are cast up to a distance of 35 feet. Seeds are hard-coated, and may lie viable in the ground for many years. Their germination is increased by fire, however, many seedlings emerge in openings each year in the absence of fire. The leaf fall is large, and a deep litter accumulates beneath the shrubs. No new seedlings become established under dense brush.

FIGURE 6. With protection from browsing, wedgeleaf ceanothus grows rapidly (left) and may produce seed within four or five years, but with heavy browsing the plants may be kept low (right) and within reach of deer for many years.

Sometimes wedgeleaf ceanothus becomes very dense, and no herbaceous vegetation grows in the understory. When such areas are burned, new seedlings emerge in great abundance and grow rapidly where there is little competition from herbaceous vegetation.

Without utilization, height growth is rapid and new plants may begin to produce seed within four to five years. With heavy deer utilization in winter, the shrubs may be suppressed so that the entire tops are kept within deer reach for 20 or 25 years (Figure 6). Under this condition the plants produce few seed, if any, and a fire through brush will greatly reduce their abundance on the range. The game manager can be sure that, if a repeat burn occurs before another seed crop is produced, both the stand and its carrying capacity for deer will be greatly reduced.

Oaks

California scrub oak and scrub interior liveoak are similar in general appearance on the Tehama deer winter range. Both are about 8 to 10 feet tall, and grow under similar situations (Figure 7). However, they can be identified by the lower leaf surface, which in California scrub oak is light blue, and in scrub interior liveoak, a glossy green. These chaparral oaks are second to wedgeleaf ceanothus in browse abundance on the Tehama range. Two other oaks have importance for deer: California black oak at higher and California blue oak at lower elevations. These oaks grow 30 to 60 feet tall. They drop their leaves in winter, while the two chaparral oaks are evergreen.

Oaks are important to deer in several ways: (1) the evergreen species provide browse in winter; (2) the new leaves of all four oaks are

FIGURE 7. Appearance of scrub interior liveoak in 1958, 11 years after it was burned. It sprouts vigorously. California scrub oak appears similar to this. (Wedgeleaf ceanothus in the foreground.)

readily eaten in the spring; (3) the dry leaves of the deciduous oaks are eaten in the fall soon after they drop (Figure 5); and (4) all species provide acorns. Although the two chaparral oaks are not highly preferred food items, they do furnish a constant and steady source of browse in winter, and may be very important when other browse is scarce. Browse of California scrub oak is preferred to that of scrub interior liveoak. Deer seem to be fond of the very young leaves of all oaks, and browse on them heavily wherever they can be reached. Deer also take a surprisingly large quantity of dry oak leaves. If deer migrate to the winter range before green grass becomes available, they apparently feed on dry oak leaves in preference to dry grass.

Acorns are an important food item to deer. They become available at a critical time of the year, often just before green grass becomes sufficient and preceding the winter months. When acorns are abundant they comprise a large percentage of the food in the fall (Figure 5). As a result the deer may become fat, and they go through the winter in better flesh and with less mortality than if acorns were not available. During the years of this study, the acorn crop varied from abundance to scarcity.

The chaparral oaks are vigorous sprouters following fire. California black oak and California blue oak also sprout, but not so vigorously as the chaparral oaks.

Western Mountain Mahogany

This is another rather abundant shrub on the Tehama deer winter range as well as throughout most of the Sierra Nevada foothill region. On the Tehama range it eventually grows into a small tree 12 to 18 feet tall. Even as a tree, however, it produces annually a few sprouts at the stem base, which are available to deer. This shrub is partly deciduous, losing about one-fourth to three-fourths of its leaves each fall. However, since the leaves drop in late September, this might be a reaction to drought conditions rather than to frost.

Stumps of western mountain mahogany sprout vigorously after fire (Figure 8). On the Tehama winter range, all stumps seen produced sprouts following the fire in 1947. The sprouts are nutritious and are readily eaten by deer and some by cattle. Stockmen also have found the sprouts to be excellent sheep browse.

The seed crop varies from very heavy in some years to very light in others. The seed has a plumose awn, and may be blown in a brisk wind a distance of 150 yards from the parent tree. Seed coats are thin and the seeds germinate readily without fire. In this respect, western mountain mahogany differs from a majority of chaparral species, most of which are favored by fire. After the seeds have fallen they are readily destroyed by fire, so that seedlings are seldom seen on areas burned intensely in the late season. However, in Madera County it was found that light fires under mature shrubs before seed fall prepare a seedbed. When this happens, new seedlings may appear in great abundance in the next growing season (Biswell *et al.*, 1953). Time of fire is therefore important to this species in reproduction from seed. The shrub is resistant to browsing on winter ranges. However, on year-long deer ranges, new sprouts following fire are browsed so heavily that many plants eventually die.

FIGURE 8. Many sprouts and dense growth of western mountain mahogany in October, 1952, five growing seasons after the fire of 1947. It was estimated that one-half to two-thirds of the leaves had fallen, probably as a result of the dry summer season rather than frost.

Yerba Santa

This shrub is widely distributed in the Sierra Nevada foothills of California. It is a pioneer species that germinates from seed the first year after fire in areas of burned brush that are mostly free of competition from herbaceous vegetation. A few seedlings may continue to emerge for two or three years after fire. Without competition, the seedlings grow rapidly and the plants reproduce thereafter by shoots from stolons that grow laterally from the parent plants (Figure 9). Such shoots may appear in the first growing season after fire and for several years thereafter. Mature shrubs are mostly three to six feet tall on the Tehama deer winter range.

This species is not well liked by any kind of livestock, and during summer scarcely any kind of animal, even goats, can be forced to browse upon it. On ranges heavily utilized by livestock, where com-

FIGURE 9. Young plant (left) of yerba santa arising from rhizome (underground stem). In fertile, moist soils new plants may begin to appear in the first growing season after fire. (Courtesy J. E. Street)

petition from neighboring plants is reduced, yerba santa can become dominant (Biswell, 1961).

Although not browsed in summer, yerba santa holds its leaves in winter and is browsed by deer on winter ranges, mainly when other, more palatable browse becomes scarce. For this reason it may occupy a more important place on the range than most people think. On the Tehama deer winter range, all yerba santa seedlings studied were browsed during the 1948 winter season. Generally, with better browse sufficient, yerba santa showed little use.

In fairly heavy brush, yerba santa dies out entirely in 20 or 25 years. In heavily utilized areas, where grazing reduces competition, it may live longer. However, the seeds remain viable in the soil for many years and the shrub appears again after the next fire. The seedlings are unusually sensitive to competition from herbaceous vegetation. On the Tehama deer winter range no seedlings were ever observed in

the areas of burned herbaceous vegetation or on the unburned portions of the range.

Manzanita

Whiteleaf and common manzanitas, both non-sprouting, grow in the central part of the Tehama range. They are scattered and grow chiefly in patches. They are less abundant than wedgeleaf ceanothus and the oaks, but are more abundant than other shrubs except on burned portions of the range where they are exceeded by yerba santa. These species, or others ecologically similar, are widely scattered in the foothills of California.

These particular manzanitas are considered inferior browse species. On winter ranges, however, the foliage of all plants may be eaten to some extent. The young plants often grow in an open enough manner that all the leaves can be picked off by deer, in which case they may die. Constant heavy browsing in winter can kill young plants in four or five years.

The manzanitas produce seed almost every year, with a heavier crop in some years than others. The seeds, with their pulp, are eaten by foxes and coyotes, and may be carried long distances by these animals. Seeds are hard-coated, and fire is essential to crack the seed coats for good germination.

Other Browse Species

Several other browse species grow on the Tehama deer winter range, but for various reasons are less important than those already discussed.

Fremont silktassel is a highly preferred and excellent browse for deer, but the shrub is not abundant on this winter range. It sprouts vigorously and produces much foliage, but the seedlings are not very competitive, and reproduction is poor. Several seedlings were observed in the shade of mature plants in an exclosure, but these grew poorly and most of them died.

Chaparral honeysuckle is another highly preferred browse found in small amounts on the study areas. However, it is not abundant enough to be of any importance for deer.

California juniper is scattered thinly over the range. A small amount of reproduction was observed. The young plants have spiny leaves and are seldom browsed. The older trees have a browse line, but since very little new foliage is produced below this established level, the tree produces little for deer.

Western hop-tree is deciduous. Most of the leaves have fallen by the time the deer arrive on the range, and the plant does not put out new leaves until shortly before the deer leave. At that time the leaves are browsed to some extent. Otherwise, it has little or no value on the range.

California laurel is scarce, and the mature leaves are not well liked by deer (Figure 10). It is an evergreen species. Following fires on year-long ranges the new sprouts are often kept browsed so closely that the plants are killed. This was observed many times on areas elsewhere where deer are resident. On the Tehama winter range the new sprouts mature so fast after fire they become unpalatable during the first season, before the deer return from their summer range.

FIGURE 10. California laurel grew rapidly after the fire, and showed practically no browsing use. (Picture taken March, 1951, three growing seasons after the fire.)

BRUSH SEEDLING STUDIES

Special attention was given to the brush seedlings that emerged in the first spring after the fire of 1947 (1948 crop) and also to those that appeared in subsequent years under various conditons. Studies were made of the survival or mortality of seedlings, during both summer and winter, height, growth, utilization by deer, and seed production.

Selection of Plots

For these studies, 30 plots, four feet square, were selected on July 7, 1948, along a 6-mile strip in about the middle of the Tehama deer winter range (Figure 3). Ten of the plots were on unburned range and 20 on burned. Of the latter, 10 were located where dense brush had burned, and the other 10 near-by where grass had burned. The 10 unburned plots were in grass, but were close enough to brush so that new seeds could be cast on them each year. Thus, three conditions were represented: (1) unburned herbaceous cover; (2) burned herbaceous cover; (3) burned brush with no herbaceous cover the first year.

The plots were selected to ensure that several to many brush seedlings would be available for study. As expected, seedlings were far more numerous on the burned brush plots without herbacous cover than they were on the other plots. After the plots were staked, the new seedlings were counted and measured. During the first four years measurements were made five times each year, and thereafter, twice a year

except in the fall of 1954 and the full year of 1959 when no measurements were made. In addition to these plots, a half-acre deer exclosure made it possible to observe non-utilized plants.

Herbaceous Vegetation

Herbaceous vegetation contributes to the deer diet. It also maintains infiltration capacity and protects the soil against the forces of rain and runoff.

In this particular study, herbaceous vegetation was of interest because it competes with brush seedlings affecting their survival and growth.

Studies elsewhere have shown a very high negative correlation between the density of herbaceous cover and number of brush seedlings surviving the dry summer period (Schultz *et al.*, 1955). With the higher grass density, fewer seedlings survived. The herbaceous plants emerge in the fall with the first rains, while the brush seedlings do not emerge until the following spring, mostly in late March and the first two weeks of April. By the time the brush seedlings emerge, the herbaceous plants have well-established root systems. In late April, May, and June, and through the summer, they dry the soil beyond brush seedling tolerance.

Estimates of density and percentage composition of plants on the study plots for five years are shown in Table 2. Only estimates of density were taken in 1948 and 1949. In 1948 only a few plants grew on the plots of burned brush, while under the other two conditions the density was about 30 percent. In 1949 the density on the burned brush plots increased to five percent, and remained the same for the other two conditions. By the third year, 1951, the differences among plots were much less (Table 2).

The effect of the fire on herbaceous vegetation was not determined. However, studies elsewhere in annual vegetation have shown that the grasses decrease somewhat in proportion, and the forbs increase. There is no significant effect on the density of the vegetation (Hervey, 1949).

On the burned brush plots, brush seedlings received practically no competition from herbaceous plants the first summer, and only slight competition the second summer. As will be seen later, the near absence of herbaceous vegetation on the burned brush plots greatly favored the survival and growth of brush seedlings the first year or two after the fire. Although the density of herbaceous vegetation on the unburned and burned herbaceous plots was about the same, competition seemed to be less on the latter, probably because the shrubs had been killed and their wide-speading roots no longer took moisture from the soil.

The figures on percentage composition of cover show several things characteristic of annual vegetation, e.g., a large fluctuation in abundance of species from year to year, and a decrease in some of the broadleaf species, such as redstem filaree with light grazing or protection. Perennial grasses increased during the period of study, probably as a result of lighter grazing.

Availability of forage to deer varied from year to year, and was strongly affected by rainfall. In the fall and early winter of 1956 the forage was particularly light because of low rainfall. In early November

TABLE 2

Average Density and Composition of the Herbaceous Cover on the Tehama Winter Deer Range Study Plots

Species	Unburned herbaceous cover					Burned herbaceous cover					Heavily-burned dense brush cover				
	1951	1952	1954	1957	1958	1951	1952	1954	1957	1958	1951	1952	1954	1957	1958
Percentage density of herbaceous vegetation	0.33	0.41	0.56	0.37	0.52	0.32	0.46	0.40	0.36	0.38	0.20	0.21	0.32	0.16	0.27
Percentage composition of cover:															
Foxtail fescue	12.3	5.0	21.5	17.5	11.5	20.0	20.0	24.0	13.5	24.0	28.9	9.0	21.5	22.5	30.5
Slender oat	2.5	1.8	8.5	4.0	6.5			1.5	1.5	1.0	3.3	3.0	1.0	5.0	5.5
Soft chess	12.4	20.7	35.0	17.0	10.5	18.7	21.5	25.0	36.0	21.5	17.6	20.5	17.0	9.0	11.5
Red brome	12.0	16.2	7.5	14.0	4.0	4.4	4.8	6.5	9.0	4.5	28.7	28.5	26.5	16.5	19.0
Ripgut brome	5.5	6.8		9.0	2.0	3.5	3.5	5.0	5.0	10.5	1.5	11.5	10.0	4.0	1.0
California melic	6.4	4.5	7.5	8.5	5.0		0.5	2.0	0.5	0.5		1.0		2.0	0.5
Malpais bluegrass						2.0	3.4	1.0	0.5						
Redstem filaree	25.5	26.5	9.5	8.0		33.3	33.5	18.5	1.0	2.5	8.4	16.5	9.0		
Hairy lotus	0.8		0.5	1.5		1.5		1.0		3.0				1.5	1.0
Godetia				2.0		1.7		1.0	4.0	4.0				4.5	3.0
Napa thistle	2.9	5.0		7.5	4.0	2.3	2.5		5.0	10.5				5.0	13.0
Clovers	1.5			1.0	0.5					0.5				0.5	
Others	18.2	13.5	10.0	10.0	26.0	12.6	10.3	14.5	24.0	14.5	11.6	10.0	15.0	19.5	15.0

the maximum height of ripgut brome was only 2 inches. On the other hand, in the fall of 1957 the forage was abundant and readily available to the deer. Other particularly poor forage years were 1949 and 1952; particularly good forage years were 1948, 1950, and 1955. In 1950, maximum height of ripgut brome on October 20 was 6 inches, and on December 29, 17 inches, and forage for deer was abundant.

The Brush Seedling Crop of 1948

The number of seedlings of the 1948 crop that survived and grew in the spring and fall of each succeeding year, with their average heights, is given in Table 3. Only four species were present on the plots: wedgeleaf ceanothus, western mountain mahogany, yerba santa, and manzanita. It is interesting that no seedlings of western mountain mahogany were found on the burned brush plots. As explained earlier, when the seeds of this species are on the ground at the time of fire they are easily destroyed. Also, there were no seedlings of yerba santa on either the unburned or burned herbaceous plots. Young seedlings of this species are extremely sensitive to competition. If any emerged, they died without being noticed.

Survival and Mortality of Brush Seedlings. Table 3 shows that: (1) Total mortality was very high under all three conditions. (2) Mortality was greatest on the unburned herbaceous plots where competition from herbaceous plants was greatest, and lowest on the burned brush plots where competition was least. (3) Mortality on the unburned and burned herbaceous plots was very high the first summer (Figure 11). Thereafter, the mortality was low on the basis of original number of brush seedlings, because most of them had died during the first summer. After four or five years, mortality ceased and any seedlings reaching

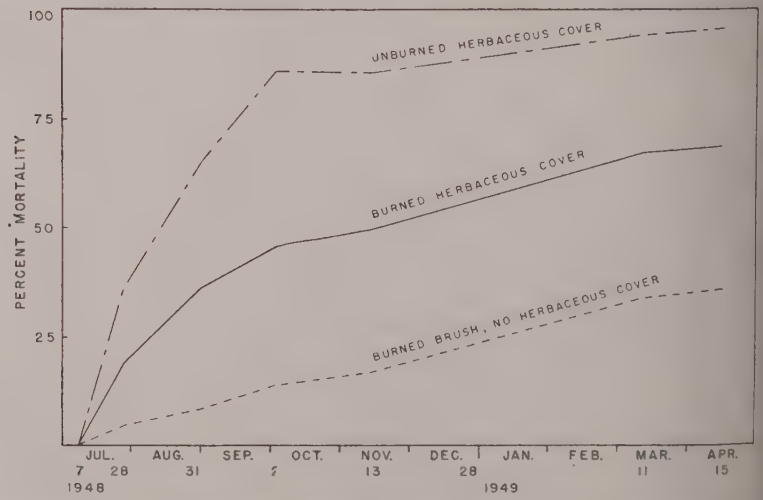

FIGURE 11. Percent mortality of wedgeleaf ceanothus seedlings for one year under the three conditions of cover.

this age had a good chance to live. On the burned brush plots, mortality was relatively low the first summer but continued for several summers thereafter. In 1960, one of the burned brush plots was bare of seedlings but the other plots were stocked each with one to 12 plants. It is obvious that mortality will continue on the more heavily stocked plots as the plants grow. (4) Mortality was very high in summer. Most of this was attributed to competition and drought. However, in some cases seedlings died during summer after being heavily browsed by deer during the winter. A few seedlings died during the summer as a result of defoliation by grasshoppers and quail. Rabbits and ground squirrels destroyed a few seedlings.

The winter mortality was also the result of several influences. In 1948-49 the winter was unusually cold, and many seedlings suffered frost damage. In some cases the roots were broken off a foot or more beneath the soil surface, and the seedlings were completely heaved out. Deer often browse all the leaves and branches from young seedlings to a point where only a one inch dead stub of the stem remains. A few seedlings, especially in their first winter on the fresh brush burn, are killed by deer trampling.

Growth and Utilization of Brush Seedlings. Growth of brush seedlings is indicated by their average heights in the fall and spring of each year (Table 3). As a result of deer browsing in winter, the seedlings were never as tall in early spring as they had been in the preceding fall. Growth and suppression of seedlings are illustrated in Figure 12, from measurements of wedgeleaf ceanothus seedlings taken over the first three years. This trend continued for the 12 years of study. However, in several cases measurements were made late in the spring after considerable growth of the year in question had taken place. In such cases the full degree of utilization was not indicated.

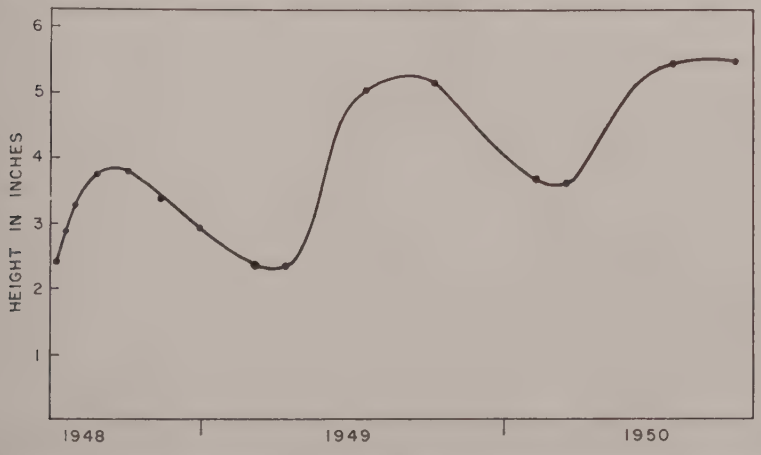

FIGURE 12. Trend in height growth of wedgeleaf ceanothus seedlings resulting from browsing in winter and growth in summer.

TABLE 3

Survival and Growth of Brush Seedlings That Emerged in the Spring of 1948
(No measurements in the fall of 1954 or the year 1959)

Species	Season	Unburned herbaceous cover		Burned herbaceous cover		Burned brush	
		No. of plants	Average height (inches)	No. of plants	Average height (inches)	No. of plants	Average height (inches)
Wedgeleaf ceanothus	July 7, 1948	87	2.30	134	2.01	242	2.56
	Fall, '48	14	3.12	72	2.49	209	3.84
	Spring, '49	5	2.40	46	2.20	175	2.41
	Fall, '49	3	3.83	26	4.25	133	5.20
	Spring, '50	2	3.00	20	3.83	125	3.65
	Fall, '50	2	5.50	14	6.71	108	5.50
	Spring, '51	1	5.00	14	5.82	104	4.98
	Fall, '51	1	8.00	13	10.69	96	8.22
	Spring, '52	1	8.00	12	12.00	84	8.85
	Fall, '52	1	8.00	12	14.83	81	10.35
	Spring, '53	1	6.00	12	12.92	74	10.07
	Fall, '53	1	8.00	12	16.25	73	13.71
	Spring, '54	1	6.00	12	15.50	71	11.45
	Spring, '55	1	5.00	12	17.42	66	13.39
	Fall, '55	1	5.00	12	19.83	65	15.80
	Spring, '56	1	5.00	12	19.67	59	15.76
	Fall, '56	1	7.00	12	22.58	58	18.74
	Spring, '57	1	7.00	12	22.92	55	17.82
	Fall, '57	1	7.00	12	24.58	55	20.82
	Spring, '58	1	7.00	12	26.42	51	21.73
	Fall, '58	1	6.00	12	29.00	51	21.90
	Spring, '60	1	5.00	12	28.10	51	24.60
Western mountain mahogany	July 7, '48	21	2.05	5	3.00	0	0
	Fall, '48	14	1.93	0		0	
	Spring, '49	9	1.90	0		0	
	Fall, '49	6	2.75	0		0	
	Spring, '50	5	2.60	0		0	
	Fall, '50	4	2.75	0		0	
	Spring, '51	3	2.00	0		0	
	Fall, '51	3	3.00	0		0	
	Spring, '52	3	3.50	0		0	
	Fall, '52	3	4.33	0		0	
	Spring, '53	3	2.83	0		0	
	Fall, '53	3	6.33	0		0	
	Spring, '54	3	3.33	0		0	
	Spring, '55	3	4.00	0		0	
	Fall, '55	3	5.67	0		0	
	Spring, '56	3	5.00	0		0	
	Fall, '56	3	6.33	0		0	
	Spring, '57	3	6.33	0		0	
	Fall, '57	3	7.00	0		0	
	Spring, '58	3	8.67	0		0	
	Fall, '58	3	9.00	0		0	
	Spring, '60	3	7.20	0		0	
Yerba santa	July 7, '48	0		0		146	3.12
	Fall, '48	0		0		125	7.55
	Spring, '49	0		0		84	6.92
	Fall, '49	0		0		77	10.52
	Spring, '50	0		0		73	10.65
	Fall, '50	0		0		43	13.62
	Spring, '51	0		0		43	12.60
	Fall, '51	0		0		43	17.88
	Spring, '52	0		0		42	20.46
	Fall, '52	0		0		42	21.20
	Spring, '53	0		0		40	22.22
	Fall, '53	0		0		39	24.55
	Spring, '54						
	Spring, '55	0		0		34	28.41
	Fall, '55	0		0		31	32.24

TABLE 3—Continued

Survival and Growth of Brush Seedlings That Emerged in the Spring of 1948

Species	Season	Unburned herbaceous cover		Burned herbaceous cover		Burned brush	
		No. of plants	Average height (inches)	No. of plants	Average height (inches)	No. of plants	Average height (inches)
Yerba santa —Continued							
	Spring, '56	0		0		29	32.24
	Fall, '56	0		0		25	32.74
	Spring, '57	0		0		23	33.91
	Fall, '57	0		0		22	29.14
	Spring, '58	0		0		19	30.79
	Fall, '58	0		0		17	29.58
	Spring, '60	0		0		8	29.75
Manzanita	July 7, '48	7	1.71	15	2.31	54	1.52
	Fall, '48	0		3	2.33	25	1.66
	Spring, '49	0		1	2.00	1	2.50
	Fall, '49	0		0		1	4.00
	Spring, '50	0		0		1	2.50
	Fall, '50	0		0		1	3.50
	Spring, '51	0		0		1	2.00
	Fall, '51	0		0		1	3.00
	Spring, '52	0		0		0	

The seedlings of different species grew at different rates. Those of yerba santa attained a maximum height of 25 inches the first summer, and new plants arose as sprouts from underground stems (Figure 9). At maturity, on the Tehama range, this plant is mainly 3 to 6 feet tall. Therefore, it makes a large percentage of its total growth the first season. The maximum height of wedgeleaf ceanothus for the first summer was 10 inches on the burned brush plots where soil nutrients were high and there was almost no competition from herbaceous vegetation. On the unburned herbaceous plots the maximum height of wedgeleaf ceanothus was only 5 inches, and on the burned herbaceous plots, 6 inches. On the burned brush plots, wedgeleaf ceanothus seedlings were vigorous while those on the other plots with competition appeared weak. During the first summer, manzanita seedlings grew a maximum of 3 inches, and western mountain mahogany, 4 inches.

Not only was growth of seedlings greatest on the burned brush plots where competition was low and soil nutrients high, but utilization was greatest there. The wedgeleaf ceanothus seedlings on the burned brush plots outgrew the others during the first summer, but by the end of the winter season they were no taller because of the heavier utilization. After a winter of browsing use, the seedlings averaged about the same height under all three conditions (Figure 13). On the burned brush plots all wedgeleaf ceanothus seedlings were browsed by the end of the winter period, but only about 30 percent of the seedlings on the herbaceous plots showed any browsing (Figure 14). There was evidence that the seedlings on the herbaceous plots were protected somewhat by old, dry grass and therefore escaped deer browsing. On the burned brush plots there was nothing to obscure the seedlings.

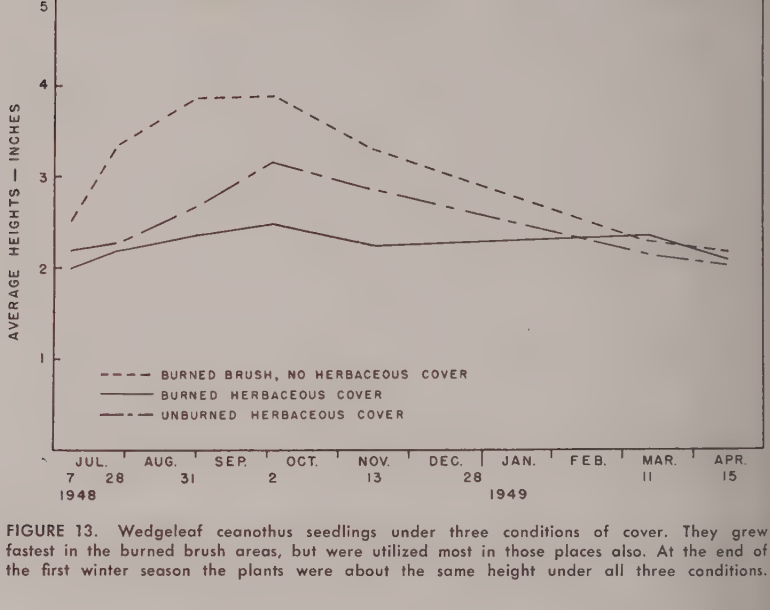

FIGURE 13. Wedgeleaf ceanothus seedlings under three conditions of cover. They grew fastest in the burned brush areas, but were utilized most in those places also. At the end of the first winter season the plants were about the same height under all three conditions.

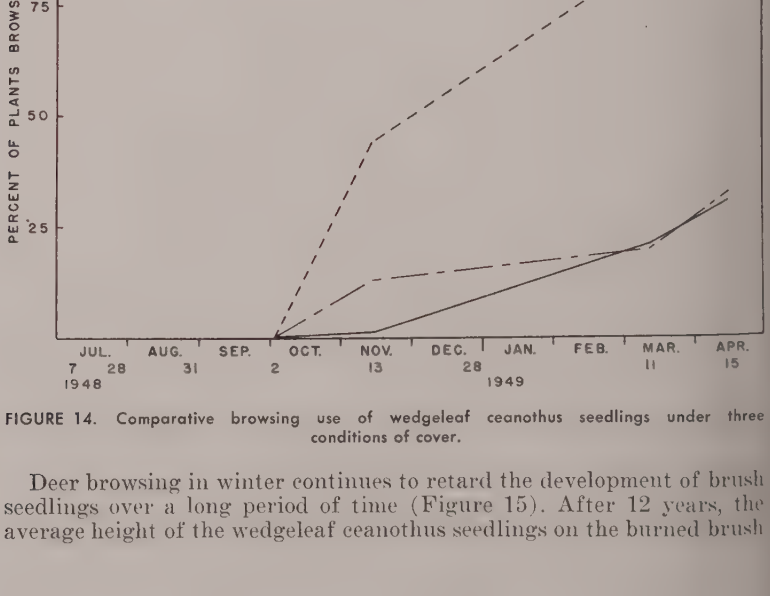

FIGURE 14. Comparative browsing use of wedgeleaf ceanothus seedlings under three conditions of cover.

Deer browsing in winter continues to retard the development of brush seedlings over a long period of time (Figure 15). After 12 years, the average height of the wedgeleaf ceanothus seedlings on the burned brush

plots was only one-third that of the mature plants. Studies elsewhere have shown that following fire this species grows fast when free of browsing and reaches maximum height in four or five years. Mountain mahogany seedlings averaged less than 1 foot tall in 12 years. Since yerba santa grows fast and was utilized less than the other species, it reached about average maximum height in seven years.

Seed Production from Seedlings. When shrubs are continually browsed each winter they are slow in developing far enough to produce seed. A few plants of wedgeleaf ceanothus produced seeds in 1956, in their ninth year (Figure 16). In 1960, after 12 years, eight plants of the 51 on the burned brush plots produced seeds, as well as five plants on the burned herbaceous plots. No seedlings of western mountain mahogany or manzanita produced seed during the 12 years, and it appeared that they would not do so for many more years. Yerba santa grows and matures fast, and produced seed during its third summer.

Brush Seedling Emergence and Survival After 1948

The emergence of new brush seedlings in the years following the 1948 crop is shown in Table 4. Yerba santa is not included because it was not always possible to decide whether a new plant came from seed or was a shoot from an underground stem. In most cases it was definitely the latter. At the close of the study in 1960, there were 28 new yerba santa plants on the burned brush plots in addition to the eight plants that still survived from the 1948 crop.

The figures in table 4 show that new seedlings started every year but the number varied greatly. Nearly all died the first summer after germination.

GROWTH AND UTILIZATION OF STUMP SPROUTS

When fires occur during the growing season, stump sprouts begin to appear in about three weeks. However, if the fire is in late September after summer growth stops, new sprouts may not appear until the following spring. In such cases, the principal food for deer in winter will be herbaceous vegetation.

The principal sprouting species on the study areas were western mountain mahogany, California scrub oak and scrub interior liveoak, and Fremont silktassel. All of these are vigorous sprouters. No plants died as a direct result of the fire. Yerba santa also sprouts following fire, but in this case there had been no plants on the range before the fire; all new growth of this species after the fire came from seed. On winter deer ranges not grazed by livestock, the sprouts have no interference during the first growing season after fire, and they grow rapidly. When the plots were established on July 7, 1948, average heights of the larger sprouts were as follows: Western mountain mahogany, 24.9 inches; California scrub oak and scrub interior liveoak, 24.9 inches; Fremont silktassel, 23.8 inches. These measurements may be contrasted with that of wedgeleaf ceanothus seedlings, which averaged only 2.5 inches on the same date. The sprouts have attained still greater heights by the end of the summer. During the following winter, Fremont silktassel especially, and the oaks were browsed back considerably by deer, but mountain mahogany, being partly deciduous, apparently

TABLE 4

Number and Survival (or Mortality) of Brush Seedlings

Species	Date	Unburned herbaceous cover	Burned herbaceous cover	Burned brush
The 1949 Crop				
Wedgeleaf ceanothus	Spring, '49	1	1	5
	Fall, '49	0	1	2
	Spring, '50	0	1	2
	Fall, '50	0	1	1
	Spring, '51	0	1	1
	Fall, '51	0	0	1
	Spring, '52	0	0	0
Manzanita	Spring, '49	0	8	3
	Fall, '49	0	0	1
	Spring, '50	0	0	0
The 1950 Crop				
Wedgeleaf ceanothus	Spring, '50	32	1	0
	Fall, '50	0	0	0
Mountain mahogany	Spring, '50	67	0	0
	Fall, '50	0	0	0
Manzanita	Spring, '50	1	0	0
	Fall, '50	0	0	0
The 1951 Crop				
Wedgeleaf ceanothus	Spring, '51	55	8	1
	Fall, '51	0	0	0
Manzanita	Spring, '51	0	0	1
	Fall, '51			1 still living in 1960
Fremont silktassel	Spring, '51	1	0	0
	Fall, '51	0	0	0
Scrub oak	Spring, '51	0	0	6
	Fall, '51	0	0	0
California black oak	Spring, '51	0	2	0
	Fall, '51	0	0	0
The 1952 Crop				
Wedgeleaf ceanothus	Spring, '52	12	1	0
	Fall, '52	0	0	0
Fremont silktassel	Spring, '52	1	0	0
	Fall, '52	0	0	0
Scrub oak	Spring, '52	1	0	0
	Fall, '52	0	0	0
Redbud	Spring, '52	0	8	0
	Fall, '52	0	0	0
The 1953 Crop				
Wedgeleaf ceanothus	Spring, '53	39	2	0
	Fall, '53	13	0	0
	Spring, '54	4	0	0
	Spring, '55	2	0	0
	Fall, '55	1	0	0
	Spring, '56	0	0	0

TABLE 4—Continued

Number and Survival (or Mortality) of Brush Seedlings

Species	Date	Unburned herbaceous cover	Burned herbaceous cover	Burned brush
The 1953 Crop—Continued				
Mountain mahogany	Spring, '53	14	0	0
	Fall, '53	8	0	0
	Spring, '54	8	0	0
	Fall, '55	0	0	0
Manzanita	Spring, '53	2	0	0
	Fall, '53	0	0	0
The 1954 Crop				
Wedgeleaf ceanothus	Spring, '54	2	6	0
	Fall, '54	0	0	0
The 1955 Crop				
Wedgeleaf ceanothus	Spring, '55	19	5	6
	Fall, '55	1	0	0
	Spring, '56	1	0	0
	Fall, '56	0	0	0
Fremont silktassel	Spring, '55	0	0	1
	Fall, '55	0	0	0
The 1956 Crop				
Wedgeleaf ceanothus	Spring, '56	2	0	0
	Fall, '56	0	0	0
Mountain mahogany	Spring, '56	2	0	0
	Fall, '56	1	0	0
	Spring, '57	1	0	0
	Fall, '57	1	0	0
	Spring, '58	1	0	0
	Fall, '58	0	0	0
The 1957 Crop				
Wedgeleaf ceanothus	Spring, '57	110	4	0
	Fall, '57	1	0	0
	Spring, '58	1	0	0
	Fall, '58	0	0	0
Mountain mahogany	Spring, '57	21	0	10
	Fall, '57	1	0	6
	Spring, '58	1	0	5
	Fall, '58	0	0	5
	Spring, '60	0	0	1
Manzanita	Spring, '57	0	1	0
	Fall, '57	0	0	0
The 1958 Crop				
Wedgeleaf ceanothus	Spring, '58	10	2	0
	Fall, '58	0	1	0
	Spring, '60	0	0	0
Mountain mahogany	Spring, '58	3	0	4
	Fall, '58	1	0	4
	Spring, '60	0	0	0
Fremont silktassel	Spring, '58	1	0	0
	Fall, '58	0	0	0
Redbud	Spring, '58	0	1	0
	Fall, '58	0	0	0
The 1960 Crop				
Wedgeleaf ceanothus	Spring, '60	6	0	0
Mountain mahogany	Spring, '60	1	0	2

as a result of drought, was not browsed back appreciably. This is considerably different from utilization on year-long ranges such as the Cow Mountain area in Lake County. On that area, mountain mahogany is browsed heavily and continuously from the time sprouting begins, and as a result the plants are frequently killed.

FIGURE 15. Upper, wedgeleaf ceanothus seedlings in April, 1953, five growing seasons after the fire, show very little close utilization. This is the condition of plants when the deer leave for the summer range. Lower, wedgeleaf ceanothus seedlings on another plot in October, 1955, eight growing seasons after the fire. Shrubs are in this condition when the deer arrive from the summer range.

Sprout growth continued rapidly. By the end of the second summer, western mountain mahogany had grown to an average height of 49.3 inches, with a maximum of 67 inches; scrub oaks, 55.4 inches, maximum 78 inches; and Fremont silktassel, 35.6 inches, maximum 59 inches.

At the end of the third season, western mountain mahogany had grown to an average height of 72.5 inches, maximum 91 inches; scrub oak, 74.2 inches, maximum 95 inches; Fremont silktassel, 57 inches, maximum 71 inches. In the following season the plants gradually ap-

FIGURE 16. Upper, July, 1948, the first growing season after the fire. On the edge of the brush a few shrubs survived the fire. Lower, October, 1958, 11 growing seasons later. Note that the shrubs are spaced sufficiently that the deer can browse around each one.

proached the heights of old, well-established plants: Western mountain mahogany, 14 feet, 5 inches; scrub oak, 8 feet 9 inches; Fremont silktassel, 9 feet 2 inches.

FIGURE 17. Upper, Fremont silktassel at the end of the growing season in October, 1952 Lower, Fremont silktassel near the end of the browsing period in April, 1953.

Browsing depressed sprout growth very little except in Fremont silktassel, some of which were browsed back heavily the first summer Each winter the deer ate all of the regrowth, and this gradually weak

ened the plants (Figure 17). This plus extreme defoliation by grasshoppers in some instances caused a few of the plants to die. Regrowth on heavily utilized Fremont silktassel plants during the summer after the first winter of browsing averaged 5.4 inches per plant; in 1950 it averaged 3.9 inches; and in 1952, only 1.3 inches. Thus, the measurements showed gradual weakening in the plants as the seasons passed. In contrast, unbrowsed plants showed good growth. For example, in 1952, when regrowth on heavily utilized plants was only 1.3 inches, the growth on protected plants was 9.7 inches.

Seed Production from Sprouts

In contrast to the slow growth of seedlings and their development to the seed producing stage, sprouts grew much faster and produced seed at an earlier age. California scrub oak produced a few seed in 1950, the third year of sprout growth; western mountain mahogany in 1952, the fifth year of growth; and Fremont silktassel in 1955, the eighth growing season.

UTILIZATION OF MATURE WEDGELEAF CEANOTHUS

Utilization of mature wedgeleaf ceanothus plants on the range was estimated during three seasons by Dasmann (1950). In addition, the authors measured utilization in one year, near the study plots, by the marked twig method, with results very close to Dasmann's estimates. He assigned utilization figures for the three years as follows: 1947-'48, 10.6 percent; 1948-'49, 24.4 percent; 1949-'50, 16.7 percent. For the measurements near the study plots the utilization (by both methods) was about six percent. During these years all of the seedlings of this species were heavily utilized, with about three-fourths of the new height growth removed each year. It can be concluded that the seedlings of wedgeleaf ceanothus are much preferred to the nearby old plants.

DAMAGE FROM GRASSHOPPERS

Grasshoppers were abundant locally in some years. They fed heavily upon western mountain mahogany, but very little on other species. During 1958, many shrubs were completely stripped of leaves. In an area where western mountain mahogany contributes heavily to deer diet, grasshoppers could be important in reducing the range carrying capacity for deer.

DISCUSSION

The game manager should have in mind an idealized game habitat toward which he works, on the basis of the best information available. Furthermore, he should strive to improve his management plan through research and observation.

The Tehama deer winter range is already an excellent habitat for deer. However, it would be worthwhile to have more shrubs for browse in some places, and to thin them in others, especially on north exposures. In some places a new stand of brush should be initiated since the present plants are decadent and are producing little nutritious browse (Figure 18). In a few places blue oaks have thickened, and the

wedgeleaf ceanothus intermixed with them is dying out (Figure 19). Clearly, the carrying capacity of such ranges can be increased. On the other hand, the game manager is challenged with the problem of maintaining the present carrying capacity.

The objective in this research was to obtain ecological information which can serve as a basis in developing management practices to maintain and perhaps improve winter deer ranges. It is well known that browse is essential for deer, both as food and cover. Basically, deer prefer browse over herbaceous vegetation. However, if the browse is at all inferior, the diet may be made up largely of herbs—at least when they are green and nutritious. On a deer winter range where there is no new growth of shrubs until spring, the browse becomes poorer week by week as the animals select the better portions; at the same time the herbaceous forage may be utilized more and more. It can be concluded that both shrubs and herbaceous plants are necessary for the best welfare of deer on winter ranges. Browse becomes of supreme importance when snow makes the herbaceous plants unavailable to the deer.

On a deer winter range, shrubs that hold their leaves are obviously far more desirable than those that do not. Also, sprouting species may have an advantage over non-sprouting ones since they recover more rapidly after fire and are not so easily diminished by repeated burning.

Fortunately, most of the shrubs and trees on the Tehama winter range have value for deer in the proportions in which they occur. On some of the other winter ranges certain species, such as scrub interior liveoak and yerba santa, are too abundant in relation to other species; in such cases these species may not be utilized appreciably, but still

FIGURE 18. Decadent stand of shrubs now furnishing very little browse for the deer. Regeneration to a new stand is highly worthwhile in such places.

FIGURE 19. Wedgeleaf ceanothus dying out from old age and not regenerating itself in this area where the blue oak has thickened and where competition from grass is high.

they occupy space and compete with the more desirable plants. This is not the case on the Tehama deer winter range, at least to any noticeable extent.

Importance of Soil

Ecologists know that one of the most important factors governing distribution of vegetation is the underlying soil. It was pointed out that the striated nature of the vegetation on the Tehama deer range is chiefly the result of differences in soils, with the shrubs generally on the deeper soils. Over certain portions of the Tehama range it would be worthwhile to have more shrubs for browse. However, the Toomes soils predominate, and on some of the south-facing slopes they are very shallow—perhaps not over 3 to 8 inches deep—and are cemented together by tuffaceous sediments. These soils probably will not support shrubs, and are more suited to shallow-rooted grasses. If the game manager undertakes to increase shrubs, therefore, it should be on the deeper soils—perhaps where shrubs formerly grew but have died out.

Use of Fire

Controlled fire can be used to improve brushlands for game. Fire increases germination of hard-coated seeds and kills the tops of sprouting species, thereby causing new sprouts to arise from the stumps. Thus a new crop of brush is initiated which, in some cases, may be thicker than the preceding crop. The yield of browse may be greatly increased. Furthermore, deer prefer the browse of young plants and sprouts to that of older plants. Tests have also shown that the protein content and browse value of young plants and new sprouts are improved. When dense brush is burned, most of the seedlings arise during the first spring after the fire, and a few follow for one or two years thereafter. When all plants are killed by fire, no more seedlings may appear until the new plants produce seeds in the area. Some of the sprouting species on the winter range grew rapidly and began producing seed within a relatively few years, but this was not true of the non-sprouting wedgeleaf ceanothus. These plants were browsed to the point at which most of them would not produce seeds for perhaps 15 years or longer. The conclusion is, to maintain wedgeleaf ceanothus, or any other highly palatable, non-sprouting species, fire must be used judiciously. Firing of such brush before the plants mature and produce seed is sure to lower the amount of this species in the stand, and perhaps, also, the range carrying capacity for deer. After 12 years of study on the Tehama range, it appears that no one spot of wedgeleaf ceanothus can be burned more often than every 20 or 25 years, and perhaps longer where browsing is heavy, without lowering the amount of this plant in the stand. This is not the case with sprouting species. These plants produce seed much more quickly after a fire; furthermore, they regrow from stump sprouts.

How to use fire can sometimes be a problem. Always there is danger that a fire will escape and do damage elsewhere. When dense brush is pushed over, it can be burned at selected times during the fall or early spring without excessive danger of escape. Pushed-over brush can be burned the first winter season after treatment, or two or three years later, and many seedlings will start after the fire. However, if the firing is done after the first of April, the number of seedlings that emerge may be few the first year and may not appear in abundance until the following spring. By that time the grasses have increased in abundance, and afford greater competition to the brush seedlings. It is therefore wise to burn brush the first year after it is pushed over, and early enough so that seedlings will emerge during the first spring. Probably any spring burning should be completed by the first of March. Otherwise it should be held over until the next winter season. The acreage that might be burned in any one season is dependent on the amount that can be pushed over. In general, the more the better.

Fire can sometimes be used in standing brush in summer when adequate fire-lines have been prepared and when sufficient help is available to do it in one day. A permit to burn must be obtained from state Division of Forestry personnel. This kind of brush cannot be burned in standing position when the grass is green, such as might be done in chamise chaparral, because dry grass is needed to carry fire between brush plants. The acreage that might be burned in one opera-

tion will be governed very much by where the fire-lines can be established at reasonable cost and the help available to make the burn. Always, plans should provide for completing a burn within one day. With these provisions, the acreage to be burned might vary from a few hundred to 2,000 or 5,000. If a burn is made in July or early August many sprouts will be available for deer during the next winter.

Plant Competition

Competition from other vegetation is important in preventing brush increase. On the Tehama winter range many brush seedlings emerged nearly every year in those places where old plants produced seeds; however, nearly all of them died as a result of competition. Following the fire, most of the seedlings in the burned herbaceous vegetation also died as a result of competition. In the burned brush areas competition was not so great, and enough seedings survived to insure an adequate stand of brush by the time the plants reach maturity. On the burned brush areas only one plot was without a seedling in 1960 and the others had one to 12, far more in most cases than could be supported when the plants reach maturity.

Competition from herbaceous vegetation was the main cause of seedling mortality on the Tehama deer winter range. The question is: What can be done to reduce such competition? It must be remembered that herbaceous vegetation starts growth in the fall, and brush seedlings start growth in the spring. Also, the annual herbs mature in early May, while the brush seedlings grow throughout the summer. The annual vegetation depletes the soil of its moisture, and leaves little for summer-growing brush seedlings and, perhaps, summer weeds. Heavy cattle grazing for a year or two before the annuals mature might be a means of reducing competition and favoring brush seedlings. Grazing reduces the water-using capacity of these plants and results in more summer-growing plants, such as weeds and brush seedlings. Heavy grazing followed by late rains creates conditions favorable for brush seedling survival. This method of reducing grass competition was not tested on the Tehama deer winter range, and there might be some question about the wisdom of using it as a management practice because of the possibility of increased runoff and erosion. However, this method warrants observation and study.

Another method for reducing competition and preparing a seedbed would be to scrape the soil surface with a bulldozer blade to a depth of 1 or 2 inches, before seed fall. This could be in the late spring while the soil is still moist or later during seed fall. The scraping could extend out for 30 feet or so around wedgeleaf ceanothus shrubs since the seeds are cast about 35 feet from the parent plants, and farther for western mountain mahogany since the seeds of this plant might be blown up to 150 yards in the wind. This method would be limited to the less rocky areas, but is one well worth testing.

Deer Browsing and Other Factors

Deer browsing was not an important factor in seedling mortality. However, it does retard growth of plants and delays seed production. It was pointed out that new plants of wedgeleaf ceanothus following

fire might not produce seed in appreciable amounts for 15 or 20 years. If a reburn should occur during that time, the shrub would be diminished in abundance. Therefore, in a burning program it is important to time the fire with seed production.

Other factors causing a small amount of mortality were frost heaving the first two or three years after fire, rodents and rabbits, and defoliation by quail and grasshoppers.

Planting of Browse

Planting brush seeds may be a means of increasing browse, but needs further testing. Research indicates that successful planting requires careful selection of site and preparation of seedbed to reduce competition. Successful planting might be accomplished by seeding in scraped bulldozer lanes on well-suited soils. In one test, J. L. Hiehle of the California Department of Fish and Game, obtained an excellent stand of wedgeleaf ceanothus seedlings by planting treated seeds. However, all seedlings died within two or three years as a result of competition. Just before planting, the seeds were treated by dropping them in boiling water and allowing the water and seeds to cool overnight. The seeds are not killed by the boiling water. In fact, Clarence Quick (1959) found that seeds of certain ceanothus species would germinate after 25 minutes of constant boiling in water. Planting of treated seeds in suitable places needs further testing before sound recommendations can be made.

SUMMARY

Studies of browse conditions and reproduction in relation to fire and other environmental factors were made on the Tehama deer winter range over a period of 12 years.

Fire resulted in more brush seedlings and sprouts and better range for deer. However, fire must be used judiciously or the nonsprouting species will be diminished in abundance and the carrying capacity may be decreased.

In the absence of fire, a few to many brush seedlings emerged in different years, but nearly all died. Mortality was mainly caused by plant competition. Other factors of less importance were frost heaving, browsing by deer, cutting by rabbits and rodents, and defoliation by grasshoppers and quail. Research is needed on methods of reducing competition to increase brush seedling survival, and on other means of increasing browse for deer.

ACKNOWLEDGMENTS

During the period of study, able assistance was furnished by many individuals to whom we gratefully express appreciation, particularly James Street, James Mallory, Rex Pieper, and Robert Gibbens of the University of California; and Herbert Hagen, Jack Hiehle, and William Dasmann of the California Department of Fish and Game.

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GRASS REDUCES BITTERBRUSH PRODUCTION[1]

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Land managers are gravely concerned about bitterbrush (*Purshia tridenta*) mortality on many ranges in the West. On many areas the loss has been due to overgrazing by big game and livestock; on other areas the cause is not clear. This paper reports a study of one possible cause that is especially important in the arid West—competition for soil moisture.

The study was done in an area where sizable blocks of bitterbrush have died from unexplained causes. Although it is too early to tell whether competition caused the mortality, the results do show that competing grasses reduced bitterbrush growth and production significantly.

THE STUDY AREA

The study area is located in the northeastern corner of California east of Mt. Hebron on the Klamath National Forest. Commercial quantities of ponderosa pine grew on the area until about 20 years ago when most of the mature pine was clear-cut. Now clumps of pole-sized pine, and a few mature trees, are scattered through the area (Figure 1). Dense stands of bitterbrush occur generally over the area, along with big sagebrush (*Artemisia tridentata*), rabbitbrush (*Chrysothamnus* spp.), and mountain-mahogany (*Cercocarpus ledifolius*). Perennial grasses in the herbaceous understory include: bottlebrush squirreltail (*Sitanion hystrix*), Idaho fescue (*Festuca idahoensis*), western needlegrass (*Stipa occidentalis*), and sedge (*Carex* sp.). Cheatgrass (*Bromus tectorum*), mule's ear (*Wyethia mollis*), and miscellaneous forbs are also present.

Perennial grasses are not particularly dense. Line intercept transects run in an area of complete bitterbrush die-off intercepted about 1.6 feet of perennial grass basal area per 100 feet of line. Many of the perennial grass plants are growing under the bitterbrush plants (Figure 2).

The Forest Supervisor estimates average annual precipitation at about 20 inches, much of it falling as snow. This study was made in 1960, the second dry year in a row. At Tulelake, the closest weather station with long-term means available, precipitation was 59 percent of the 25-year average in the 1958-59 season and 81 percent in 1959-60.

The bitterbrush on several sizable blocks has died almost completely except under small islands of pine. As nearly as can be determined, die-off has been heavy for at least 15 years. The largest of these blocks

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FIGURE 1. General view of a bitterbrush die-off area near Mount Hebron, California.

of complete die-off is about 200 acres. This study was located in a die-off area of only about 27 acres because it was felt that there was a better chance that the die-off was still going on here.

The problem is not limited to areas of complete die-off. All of the bitterbrush stands in the U. S. G. S. Bray quadrangle were mapped and classified as to their condition. This map, which takes in only part of the problem area, covers 160,000 acres. Bitterbrush grows on more than 53,000 acres. Criteria used for classifying the stands were as follows:

Excellent: Bitterbrush in a healthy vigorous state. No dead plants and practically no dead material within individual plants.

Good: Bitterbrush in a healthy vigorous state. No dead plants but 10 to 20 percent of the plants contain a maximum of 15 percent dead material.

Fair: Up to 25 percent of the bitterbrush plants dead, and 30 to 40 percent of the live plants contain as much as 60 percent dead material. Remaining plants in good condition.

FIGURE 2. A dead bitterbrush plant showing dense perennial grass understory.

Poor: Up to 90 percent of the plants dead. Most remaining plants have some dead material.

Die-off: Ninety percent or more of the bitterbrush plants dead.

The breakdown of bitterbrush condition classes in the Bray quadrangle is as follows:

Class	*Area, acres*	*Percent*
Excellent	0	0.0
Good	2,630	4.9
Fair	45,623	85.0
Poor	4,657	8.7
Die-off	734	1.4
Total	53,644	100.0

None of the stands in the Bray quadrangle were good enough to be classed excellent although some in adjoining quadrangles do come up to the specifications for an excellent stand.

The area has been grazed by livestock for at least 80 years. Livestock use was much greater in the early days than it has been since the advent of grazing regulations by the U. S. Forest Service. Bitter-

brush plants apparently did become established either during or immediately after rather heavy livestock use. One possible explanation for the current downward trend of bitterbrush condition is that the reduced grazing has permitted an increase in competition for moisture from perennial grass. The purpose of this study was to determine the effect that competition from perennial grass has upon the vigor and production of bitterbrush.

METHODS

Two 75 x 75 foot areas were selected and fenced against livestock in 1958. Both of these exclosures were near an area of total die-off. In one, adjacent to the die-off, the bitterbrush was in poor condition. The other exclosure was further from the edge of the die-off. Here, the bitterbrush was in fair to good condition. Half of each of these plots was weeded of everything but bitterbrush in 1959 and reweeded in 1960.

Measurements of average leader length and average number of leaders per branch were made on 15 randomly selected plants on each plot in

FIGURE 3. The finger is pointing at the first main fork of old wood. The two branches above this fork were the type of sampling units used in this study.

the fall of 1960. A branch was defined for this study as that portion above the first fork of old wood (Figure 3). Four such branches were selected on each bush, one from each quarter.

Every attempt was made to keep bias out of this branch selection. This was done by facing away from the plant, reaching behind, grabbing terminal leaders, and then following down to the first main fork. Once a branch was selected, all leaders on it were measured. A leader was considered to be any new growth over ½ inch long. Previous studies have shown that 19 to 39 leaders are needed for an accurate estimate of average leader length (Hubbard and Dunaway, 1958).

In this study 50 leaders were measured on each bush to insure an accurate estimate. Some bushes did not have 50 leaders on the 4 branches selected. In such cases, additional branches had to be selected. The estimate of average number of leaders per branch was based entirely, however, on the first four branches.

RESULTS AND DISCUSSION

Effect of Weeding on Leader Length

Removal of perennial grass and weed understory caused a dramatic increase in leader length on both plots (Figure 4). Average leader length on plants in good condition was 1.4 inches on the unweeded portion, and 2.1 inches on the weeded area. Average leader length on poor condition plants was 0.9 inches on the unweeded portion, and 1.7 inches on the weeded.

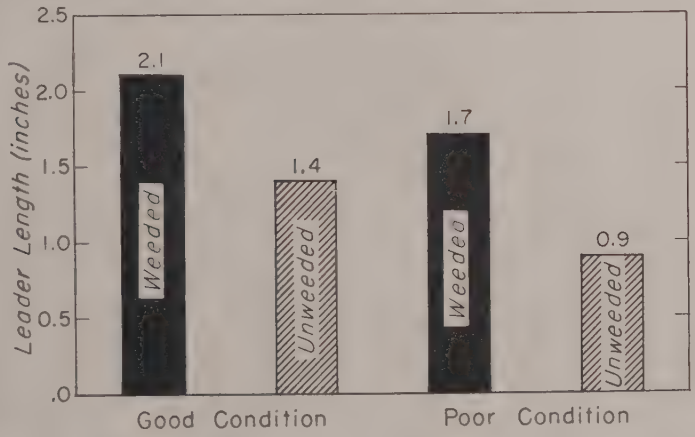

FIGURE 4. Average leader length on bitterbrush in fenced plots in the Mount Hebron die-off area.

Looking at the analysis of leader lengths (Table 1), we find the effect of the weeding treatment was highly significant (99 percent level). The difference between the good and poor condition plots was also highly significant—even though leader growth on the weeded plants in the poor condition plot was essentially the same as that on the unweeded plants in the good condition plot. The reason for the highly significant

TABLE 1

Analysis of Variance of Leader Lengths Found on Weeded and Unweeded Fenced Plots in the Mt. Hebron Bitterbrush Die-off Area

Source of variation	d. f.	Sum of squares	Mean square	F.
Leaders	49	35.41	0.72	.88
Plants	14	114.53	8.14	9.93**
Treatments (T) (weed)	1	426.57	426.57	520.20**
Condition (C)	1	149.74	149.74	182.60**
(C) X (T)	1	0.59	0.59	.71
Error	2933	2,407.26	0.82	
Total	2999	3,134.10		

** Significant at the 0.01 level.

difference between conditions was, apparently, the wide range between the relatively long leaders on the good, weeded plants and the extremely short leaders on the poor, unweeded plants.

The interaction between condition and weeding was not significant, meaning that the response to weeding was not related to plant condition. This lack of relationship can also be shown by comparing gains in leader length due to weeding on the two plots. On the good condition plot, the gain was 0.7 inch; on the poor plot, 0.8 inch. Generally, you would expect that the more vigorous plants would respond more strongly to release. That they didn't suggests that competition from the understory was more severe on the poor condition plot.

Effect of Weeding on Number of Leaders

The response to weeding in term of number of leaders produced is much the same story as for leader length. Effects of weeding and con-

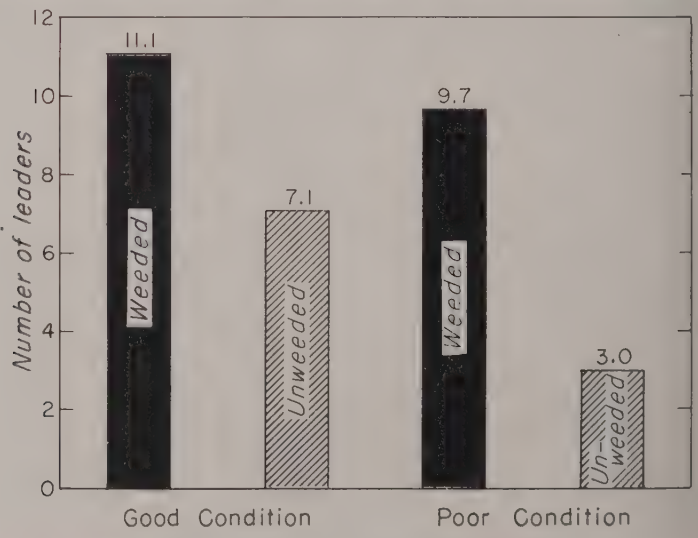

FIGURE 5. Average number of leaders per branch.

dition were, again, both highly significant (Table 2). In this test, however, the interaction between condition and weeding also was significant. The average number of leaders per branch more than trebled, from 3.0 to 9.7, following weeding of the poor condition plot (Figure 5). On the good condition plot, the increase was less than 1½ times, from 7.1 to 11.1. Here, the evidence is even stronger that competition from understory vegetation was more severe on the poor condition plot than on the good.

Both leader length and number of leaders responded similarly to weeding. Consequently both measurements are probably good indexes to plant vigor. It is sometimes difficult to measure leader length on heavily grazed plants. It may be that a leader count is a satisfactory substitute.

TABLE 2

Analysis of Variance of Number of Leaders Branch Found on Weeded and Unweeded Fenced Plots in the Mt. Hebron Bitterbrush Die-off Area

Source of variation	d. f.	Sum of squares	Mean square	F.
Branches	3	156.00	52.00	2.75
Plants	14	1,736.06	124.00	6.57*
Weeding	1	1,659.00	1,659.00	87.91**
Condition	1	478.84	478.84	25.37**
(C) X (T)	1	116.21	116.21	6.14*
Error	219	4,132.89	18.87	
Total	239	8,279.00		

* Significant at the 0.05 level.
** Significant at the 0.01 level.

CONCLUSION

This study very clearly demonstrated that competition from other plants reduces bitterbrush growth and production. Production is a function of both number and length of leaders. Both were increased by removing the herbaceous understory from plots in an area of bitterbrush mortality near Mt. Hebron, California. This study was conducted during a drought year, which undoubtedly increased the degree of competition for moisture.

The response to weeding does not prove that the understory competition is actually killing the bitterbrush—only that it is reducing production and probably vigor. Previous studies have shown that low-producing plants may hold on for many years (Hubbard, Sanderson, and Dunaway, 1960). This may be true here. Undoubtedly, heavy grazing, soils, insects, and other factors influence the mortality.

The present study will be maintained for several years, and mortality will be checked. Effects of heavy grazing will also be checked. Comparable, unfenced plots were established and weeded at the same time as the fenced plots reported here. Grazing was too heavy on these plots to get reliable estimates of leader length. On both the fenced and unfenced plots, each plant was classified as to condition and the height and diameter were measured. Also, selected plants in each plot were photographed. Changes in size and condition will be used to assess the effect of grazing and the interaction between grazing and understory competition.

The apparent close correlation between leader length and average number of leaders per branch needs further study. It may be that a count of leaders per branch is an adequate, single measure of plant vigor. If so, it will simplify and speed the gathering of information on the effect of grazing.

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CASTLE LAKE INVESTIGATION—THIRD PHASE: RAINBOW TROUT[1]

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Castle Lake, Siskiyou County (Figure 1), is fairly typical of the numerous glacial cirque lakes of western North America. It lies at the head of a steep-sided canyon at an elevation of 5,200 feet, 11 miles southwest of the town of Mt. Shasta, California. Vertical cliffs, evidence of glacial action at the canyon head, rise abruptly from the south end of the lake. It is bordered by steep mountain slopes on the east and west. At the north end the water is impounded by a low moraine.

FIGURE 1. Castle Lake, with Mt. Shasta in background. *Photograph by J. H. Wales.*

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through which the outlet stream has cut. The northern third of this 48-acre lake is shallow, with a maximum depth of 15 feet, while the remainder is a deep bowl which has a maximum depth of 122 feet and contains 1,750 of the lake's 1,900 acre-feet of water. The lake drains only 200 acres, and its water source is chiefly from snow and numerous springs. Consequently, the tributary streams are very short and steep and flow only briefly each year. They are of no value as spawning tributaries. The soil of the lake's drainage is poor, and the lake itself is low in fertility. Total dissolved solids amount to only 20 p.p.m. Secchi disk visibility ranges from 40 to 55 feet. Summer surface temperatures never exceed 75 degrees Fahrenheit. A thermocline develops in the deep, south portion of the lake in June. Complete oxygen depletion occurs below 85 feet in late summer of some years.

The authors believe that many of the conclusions derived from the Castle Lake investigation will be generally applicable to similar waters in western North America. Hutchinson (1957) expresses this point concisely: "A group of lakes confronts the investigator as a series of very complex physiochemical and biological systems, each member of which has its own characteristics and yet also has much in common with the other members of the group."

Castle Lake is especially well suited as a test water. A single access road terminates at the lake, thus enabling a creel checker to intercept and interview all anglers at the end of their fishing day. Angling pressure is high enough for adequate evaluation of various experiments by creel census.

This paper covers the third phase of the Castle Lake investigation, the rainbow trout phase. Results of this phase, covering the years 1952 through 1959, are compared with earlier results and the implications are discussed.

ACKNOWLEDGMENTS

The authors wish to thank Carl Hill and other Mt. Shasta Hatchery personnel for their help in rearing and planting the experimental fish, and George W. McCammon for his help in interpreting and presenting the data and for supervising the 1959 census.

SUMMARY OF PREVIOUS INVESTIGATIONS

The first phase of the Castle Lake investigation began in 1938, when rainbow *(Salmo gairdneri)*, brown *(Salmo trutta)*, eastern brook *(Salvelinus fontinalis)*, and lake *(Salvelinus namaycush)* trout were present. The lake also contained small populations of two cyprinids, the golden shiner *(Notemigonus crysoleucas)* and speckled dace *(Rhinichthys osculus)*.

The original design of this investigation was to stock Castle Lake for several years with equal numbers of rainbow, brook, and brown trout and from their contribution to the catch determine the one best suited to conditions existing in the lake. After the most suitable species had been chosen, it was planned to determine the best size and number to stock. The plans were evaluated by means of a complete creel census. Data on growth rates and food of the four trout species were col-

ected during this phase. Some basic limnological features were also investigated.

The results of the initial phase were reported by Wales (1946). Significant conclusions were the following:

1. The survival of stocked brook, brown, and rainbow fingerlings was very low, primarily as a result of predation by brown and naturally-spawned lake trout. Survival of subcatchable-sized and catchable-sized fish of all three species was much higher; however, maintenance plants of large fish were inefficient, since the lake's productivity was not utilized effectively.
2. Brown trout were the dominant species, providing about half of the catch in numbers and over half of the total weight of the catch. Since the interrelationships of several trout species mask the potentialities of any single species, it was decided to select one species and study its suitability to Castle Lake. The brook trout was the species chosen, because of its widespread use in other lakes of this type.

To carry out this plan, the lake was treated with rotenone at the close of the 1946 angling season. All fish were killed and the lake remained toxic to trout until July, 1947. The lake was restocked with fingerling and subcatchable-sized brook trout in 1947.[3] Additional brook trout fingerlings were stocked in August, 1948, after which brook trout plants were discontinued, since growth rate data indicated overstocking.

A complete creel census during the years 1947-53 and a five-day-per-week census in 1954 were used to evaluate the survival and growth of the brook trout plants. Wales and German (1956) reported the results of this phase of the investigation. The most important findings were the following:

1. Removal of the highly predatory brown and lake trout increased survival of brook trout fingerlings remarkably. The mean survival to the angler of planted brook trout fingerlings prior to chemical treatment was 1.9 percent, while the 1947 and 1948 plants returned 34.6 and 36.4 percent, respectively, to the creel.
2. Angling success, in terms of numbers of fish, increased, despite an appreciable increase in angling pressure. From 1941 through 1946 the mean number of angler days per year was 596 and the mean catch per angler hour was 0.61. From 1947 through 1951, the mean number of angler days per year was 1,077 and the mean catch per angler hour was 1.50. This difference is exaggerated by the contribution to the catch of a large plant of subcatchable-sized brook trout in 1947 for which plants of subcatchables and catchables in 1942 and 1943 compensated only partially. Furthermore, the average size of the fish was smaller from 1947 through 1951. In 1945 the catch per acre per year was 9.6 pounds, while the mean for the years 1947-51 was 10.3 pounds.

[3] In California, hatchery trout are classified as follows:
Fingerlings—one ounce each or smaller.
Subcatchables—larger than one ounce each, but smaller than six fish to the pound.
Catchables—six fish to the pound or larger.

3. In the absence of other species, the brook trout established a self-sustaining population. Brook trout spawn successfully in the numerous springs near the east shore of Castle Lake. Rainbows cannot reproduce in the lake.
4. It was hypothesized that a combination of brooks and rainbows in Castle Lake would provide a greater yield than brooks alone.

In 1952 the rainbow trout phase of the investigation was begun. Experimental lots of marked rainbow fingerlings were introduced each year from 1952 through 1958. The primary objectives were to determine (1) the effect of the rainbow on the fishery, (2) the strain of rainbow that would provide the highest returns to the angler commensurate with a good growth rate, and (3) the number of that strain that should be stocked annually to provide the best returns to the angler.

Secondary objectives included a comparison of the survival of catchable-sized and fingerling rainbow; a comparison of the survival of air- and truck-planted fingerlings; determination of the effect of sodium amytal on the survival of air-planted fingerlings; a comparison of the survival of fingerlings fed liver and ocean fish with that of fish fed dry pellets exclusively.

Creel Census Methods

In 1952 and 1953 all plants were evaluated by complete creel census. In 1954, a five-day-per-week census was initiated, following Best and Boles (1956). Their method requires that all week ends and holidays be censused, and that no particular day is missed during two consecutive weeks. Data for non-census days are estimated by averaging data from the same day in the week previous and the week subsequent to the one in question.

All fish were measured to the nearest tenth of an inch, fork length, and weighed to the nearest hundredth of a pound. This information was recorded on individual census forms, in addition to the name and county of the angler, hours fished, and the bait and fishing method used. In 1959 data were recorded on Unisort punch cards, in order to expedite data processing.

RESULTS AND DISCUSSION

Angler Use and Success

Table 1 summarizes angling data for the eight-year period, 1952 through 1959.

Angling success during the rainbow trout phase was relatively high, with a mean catch per angler hour of 1.0 trout.

Fishing pressure dropped appreciably during the last two years of the rainbow trout phase. This was probably due to the deterioration of the Castle Lake road and the development of good trout angling in nearby Dwinnell Reservoir.

Total catch during this phase reached a high in 1955 of 6,066 trout and then dropped to the low for the period, 2,548 trout, in 1956. The abnormally large catches in 1952 and 1955 resulted from plants of catchable-sized rainbows.

Castle Lake: Summary of Angling Data, 1952 Through 1959

	1952	1953	1954	1955	1956	1957	1958	1959
Fishing season days	167	155	171	164	165	187	167	175
Number angler days	1,087	1,429	1,079	*1,145	1,142	1,610	843	879
Total catch	4,506	3,988	2,957	6,065	2,548	4,127	2,693	2,863
Average catch per angler day	4.14	2.79	2.74	5.30	2.23	2.56	3.19	3.26
Average catch per angler hour	1.24	0.83	0.86	1.48	0.66	0.81	1.05	1.06
Average hours fished per angler	3.34	3.35	3.20	3.58	3.36	3.20	3.03	3.01
Rainbow trout caught	2,326 (52%)	2,160 (54%)	485 (16%)	1,595 (76%)	1,231 (48%)	2,850 (69%)	1,833 (68%)	2,087 (73%)
Eastern brook trout caught	2,180 (48%)	1,828 (46%)	2,475 (84%)	1,170 (24%)	1,317 (52%)	1,277 (31%)	860 (32%)	776 (27%)
Pounds of rainbow trout caught				873.7	230.7	446.8	460.4	433.4
Pounds of eastern brook trout caught	456	350	496	294.7	282.5	220.4	153.4	184.4
Average weight of eastern brook trout caught (pounds)	0.209	0.191	0.200	0.195	0.215	0.173	0.178	0.238
Average weight of rainbow trout caught (pounds)				0.490	0.187	0.157	0.251	0.208
Pounds of fish caught per surface acre	--	--	--	24.3	10.7	13.9	12.8	12.9
Number of individual anglers	662	1,163	227	639	647	868	472	472
Number and percentage of individual anglers catching 50% of total catch	83 (12.5%)	257 (22%)	39 (14%)	80 (12.5%)	43 (6.7%)	69 (7.9%)	38 (8.0%)	34 (7.2%)
Number and percentage of limit catches	79 (77%)	41 (3%)	52 (5%)	97 (9%)	30 (3%)	41 (3%)	21 (2.5%)	36 (5%)
Number and percentage of zero catches	359 (33%)	554 (39%)	524 (49%)	-- --	538 (47%)	513 (32%)	257 (31%)	284 (40%)

* During the first three months the checker failed to record all zero catches; therefore, the total number of angler days and catch per unit of effort are not comparable with those of other years.

The percentage of individual anglers taking 50 percent of the total catch ranged from 22 percent in 1953 to 6.7 percent in 1956. Since 1956 this percentage has been 8 or less.

In the two years in which catchable trout were stocked (1952 and 1955) the percentage of limit catches was the highest (7 and 9 percent, respectively). During the other six years the percentage of limit catches ranged between 2.5 and 5.0 percent.

The percentage of zero catches recorded during this phase ranged from 31 percent in 1958 to 49 percent in 1954.

The rainbow trout catch fluctuated considerably during this period (Figure 2). The brook trout catch declined steadily after 1954.

The mean weights of brook and rainbow trout taken from 1955 through 1959 were almost identical, being 0.194 pound for the rainbows and 0.199 pound for the brooks. Although their mean size was comparable with that of the rainbows, brook trout attained a greater maximum size in Castle Lake during this period. For example, during 1959 only one rainbow over 11 inches (11.2) was caught, whereas 12 brooks larger

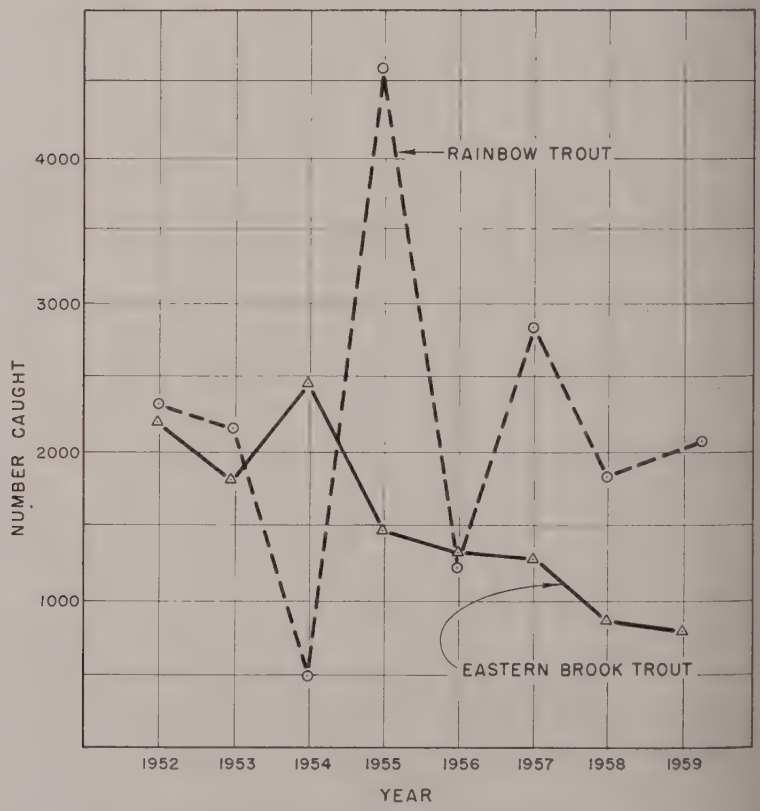

FIGURE 2. Castle Lake: Catch of rainbow and eastern brook trout, 1952 through 1959.

than this were taken, including two that were 12.8 inches and one that was 20.0 inches in length. The latter was a ripe female weighing 4.25 pounds and was the largest brook ever recorded from the lake.

The annual yield of Castle Lake from 1956 through 1959 ranged from 10.7 to 13.9 pounds per acre. The yields for 1958 and 1959 (12.8 and 12.9 pounds per acre, respectively) are believed to more closely approach the lake's potential under the brook trout-rainbow trout combination than those during the first six years of the study because: plants of catchable-sized rainbow influenced the earlier yields; large fluctuations in rainbow abundance occurred in the first six years; the age composition of the catch was "more natural" in 1958 and 1959.

Secondary Experiments

The primary results of the rainbow trout phase have been somewhat obscured by the many variables introduced by secondary experiments. Six new variables in several combinations were added to the primary tests of strains and numbers of rainbows. In 1952 and 1955 catchables were stocked. An airplane plant was compared with a truck plant in 1952, while in 1953 equal lots of drugged and undrugged fish were airplanted. Fish reared on different diets were introduced in 1957. The size and condition of fish and the planting date also varied considerably. Data of value to management were gained from these secondary experiments; however, their masking effect appreciably reduced the value of the data in regard to the primary objectives.

From 1952 through 1958, 16 lots of rainbow trout were stocked in Castle Lake. The total catch and the percentage caught from each lot are presented in Table 2. Table 3 describes each lot, and gives other pertinent information. These data lead to the following conclusions:

TABLE 2

Castle Lake: Total Catch of Each Group of Rainbow Trout, 1952-1959

Date planted	Number planted	Species	Size	Mark	Total catch	Percentage caught
July 8, 1952	2,500	RT	7.8 per pound	RV	2,027	81.1**
July 8, 1952	2,500	RT	13.1 per pound	LV	1,807	72.3**
July 4, 1952	2,500	RT	18.5 per ounce	Ad-RV	525	21.0**
July 4, 1952	2,500	RT	20.0 per ounce	Ad-LV	292	11.7**
July 4, 1952	*1,000	RT	20.0 per ounce	not marked	319	31.9**
Sept. 2, 1953	3,000	RT	8.5 per ounce	RP	79	2.6**
Sept. 2, 1953	3,000	RT	8.3 per ounce	LP	109	3.6**
Aug. 9, 1954	5,000	RT-FS	13.0 per ounce	LV-RV	1,276	25.5**
Sept. 17, 1954	5,000	SH	18.0 per ounce	Ad-LV-RV	221	4.4**
June 15 & 17, 1955	3,833	RT-FS	5.0 per pound	RP-RV	3,258	85.0**
June 15, 1955	980	RT-FS	5.0 per pound	LP-RV	750	76.5**
July 7, 1955	5,470	RT-K	16.0 per ounce	Ad-RP	995	18.2**
Aug. 14, 1956	14,858	RT-FS	19.0 per ounce	RV	4,350	29.3
Aug. 16, 1957	5,477	RT-FS	16.1 per ounce	Ad-RV	115	2.1
Aug. 16, 1957	4,523	RT-FS	9.3 per ounce	Ad-LV	260	5.7
July 28, 1958	20,000	RT-FS	20.9 per ounce	LV	1,158	5.8

* This group was planted accidentally and the exact number is not known.

** Returns all in or nearly so.

RT — rainbow trout; RT-K — Kamloops rainbow trout; SH — steelhead rainbow trout; FS — fall-spawning.

1. The mean return to the angler of the 1952 and 1955 plants of catchable-sized, fall-spawning, domestic rainbows was 79.9 percent.
2. The percentage of the 1952 plant of 2,500 rainbow trout weighing 7.8 per pound returned to the angler was slightly better than the return from an equal lot of smaller fish weighing 13.1 per pound. These two lots returned 81.1 and 72.3 percent, respectively. However, the larger fish weighed 321 pounds when planted and returned 462 pounds to the angler, whereas the smaller weighed 191 pounds when stocked and 338 pounds when caught. In terms of weight stocked, the smaller fish gave a substantially higher return.
3. In addition to their more efficient use of the lake's fish-producing potential, plants of small-sized trout are more economical. The cost in the creel of catchable-sized rainbows ($0.19 each) is almost four times as much as the cost of fingerlings ($0.05 each) in Castle Lake. This is based on an average return of 80 percent for catchables and 20 percent for fingerlings (the mean return of four truck plants of undrugged rainbow fingerlings of the domestic strain—the 1952, 1954, 1956, and 1957 plants). Catchables and fingerlings cost $0.15 and $0.01 each, respectively, to produce (Ward and Kier, 1959).
4. The 1952 truck plant of 2,500 rainbows, 18.5 per ounce, returned considerably better than an equal lot of air-planted rainbows, 20.0 per ounce. These two plants returned 21.0 and 11.7 percent, respectively, to the anglers.

TABLE 3

Castle Lake, Rainbow Trout: Description of Planted Fish

1952—2,500 RT-FS, 7.8 per pound, marked RV
Planted to provide fishing, to show returns from a plant of catchable rainbow, and to compare returns of this lot of top grade fish with the following lot of medium grade.
2,500 RT-FS, 13.1 per pound, marked LV
Medium grade of sorted fish for comparison with above lot.
2,500 RT-FS, 18.5 per ounce, marked Ad-RV
Planted at lake shore from standard tank truck, without drugs, for comparison with following lot.
2,500 RT, 20.0 per ounce, marked Ad-LV
Planted from airplane, without drugs, for comparison with above lot.
1,000 RT, 20.0 per ounce, not marked
Planted from airplane by mistake. Exact number in doubt.

1953—3,000 RT-FS, 8.5 per ounce, marked RP
Planted from airplane; carried from the Siskiyou County airport in sodium amytal solution (3 grains per gallon).
3,000 RT-FS, 8.3 per ounce, marked LP
Planted by airplane without drug for comparison with above lot. These were planted on the same flight but on the two passes following the above.

1954—5,000 RT-FS, 13 per ounce, marked LV-RV
Planted by truck, without drug, at lake shore for comparison with steelhead fingerlings.
5,000 SH, Snow Mt., 18 per ounce, marked Ad-LV-RV
Planted by truck, without drugs. Hatched and reared at Darrah Springs Hatchery.

TABLE 3—Continued

Castle Lake, Rainbow Trout: Description of Planted Fish

1955—3,833 RT-FS, 5 per pound, marked RP-RV

Planted for comparison with following lot of tagged fish, and to obtain data on percentage return to the creel.

980 RT-FS, 5 per pound, marked LP-RV and tagged

Same as the lot above but also marked with subcutaneous tags by R. L. Butler and assistants.

5,470 RT-K, 16 per ounce, marked Ad-RP

Kamloops eggs from British Columbia were hatched and reared at Mt. Shasta Hatchery. This lot suffered considerably from diseases in the hatchery. Their gills were badly infected with blood flukes, *Sanguinicola.*

1956—14,858 RT-FS, 19 per ounce, marked RV

Eggs from Hot Creek Hatchery brood stock, hatched and reared at Darrah Springs Hatchery. Appeared to be in good condition at planting time. No abnormal mortality in lot held in live cage.

1957—5,477 RT-FS, 16.1 per ounce, marked Ad-RV

Fingerlings from Mt. Shasta Hatchery brood stock, fed standard liver and ocean fish diet. Their health seemed to be inferior to the following lot fed pellets, but this was not necessarily due to the diet.

4,523 RT-FS, 9.3 per ounce, marked Ad-LV

Fingerlings from Mt. Shasta Hatchery brood stock, fed Rangen pellets almost exclusively. Their health seemed to be superior to the lot above. Five hundred of each of these two lots held in a live cage for a week suffered no unusual mortality.

1958—20,000 RT-FS, 20.9 per ounce, marked LV

Fingerlings from Mt. Shasta Hatchery brood stock, fed the standard liver and ocean fish diet. The condition of these fish seemed to be satisfactory at the time of planting. They will be compared with plants of rainbow fingerlings made in 1956 and 1957 in respect to growth rate and survival to the angler.

5. The return from the 1953 air plant of 3,000 undrugged rainbows, 8.3 per ounce, was slightly better than that of an equal lot of drugged air-planted rainbows, 8.5 per ounce. The return to the angler from these two plants was only 3.6 and 2.6 percent, respectively. On the basis of the 1952 and 1953 air plants, it appears that at Castle Lake the return to the angler is appreciably less from air plants than from truck plants.
6. The 1955 plant of 3,833 untagged rainbows, 5.0 per pound, returned significantly better (at the 0.5 percent level) than 980 of the same lot tagged with an experimental subcutaneous tag. Eighty-five percent of the untagged and 76.5 percent of the tagged fish were caught by anglers.
7. The 1957 plant of 4,523 rainbows, 9.3 per ounce, raised on Rangen pellets, have returned a greater percentage to the angler than a lot of 5,477 rainbows 16.1 per ounce, fed the standard liver and ocean fish diet. Through 1959, 5.7 percent of the former and 2.1 percent of the latter plant had been caught by anglers. A few more returns are expected from these fish during 1960. Unfortunately, there is no way of determining what part of the greater return of the pellet-fed fish is due to the pellet diet and what part is due to their larger size at planting. The results of this test are, therefore, inconclusive.

Comparison of Rainbow Strains

Data are still insufficient to determine the best rainbow strain for stocking in Castle Lake. However, the Castle Lake investigation has now entered a new phase of higher priority and, although the present data are deficient with respect to the best strain of rainbows for the lake, a decision regarding the strain of fingerlings that appeared to be best suited to the lake had to be reached, so that the current study could proceed.

Four truck plants of undrugged fingerlings of the domestic fall-spawning strain stocked in 1952, 1954, 1956, and 1957 have produced a mean return to the angler of 19.0 percent through 1959. This mean is expected to approach 20 percent when all of the returns from the 1956 and 1957 plants are in. Anglers harvested 21.0 percent of the 1952 plant, the first fingerling plant of the rainbow trout phase. These fingerlings had four days to become acclimated before a plant of 5,000 catchable- and subcatchable-sized rainbows was made. The 1954 plant returned 25.5 percent and was made when the population of rainbows in Castle Lake was very low (only 483 rainbows were caught in 1954). The 1956 plant of 14,858 domestic fingerlings had returned 29.3 percent through 1959, making it the most successful fingerling rainbow plant in Castle Lake. This plant also was made when the population of large rainbows in the lake was low (Figure 2). In fact, the yield of all trout during 1956 was low, amounting to only 10.7 pounds per acre (Table 1). The poor return of the 1957 plant (3.8 percent) may be attributed chiefly to their being stocked when the large 1956 plant was near the peak of its predatory potential.

In general, fingerling rainbow plants made in Castle Lake when the population of larger rainbows was low exhibited good survival to the creel and those made when the population of larger rainbows was high exhibited poor survival. Largely as a result of this, the rainbow population in Castle Lake has undergone definite annual fluctuations in abundance, as reflected by the annual catch (Figure 2). The results of a similar study carried out on Weber Lake, Wisconsin, by Burdick and Cooper (1956) emphasize the importance of stocking rainbow fingerlings in lakes at a time when populations of larger fish are low, especially when small fingerlings are concerned. In the Wisconsin study, successful plants alternated with unsuccessful plants, the successful plants being stocked in the even years and the unsuccessful plants in the odd years from 1945 through 1950. The data from the two studies suggest that some trout lakes could be more efficiently managed with rainbow fingerlings by planting in alternate years, instead of annually, as is customary.

Only two other rainbows, steelhead rainbow trout (*Salmo g. gairdneri*) from the Eel River, California, and Kamloops rainbow trout (*S. g. kamloops*) from British Columbia, were compared with the domestic strain. Six plants of the domestic strain were made through 1957, whereas only one plant of each of the other two groups was made.

The return of the 1954 plant of 5,000 steelhead fingerlings was very low. Only 4.4 percent (221 fish) of this plant were caught, while 25.5 percent (1,276 fish) were caught from an equal number of domestic fingerlings planted the same year. Unfortunately, the results of this test are clouded by the fact that the steelhead were released five weeks after

the domestic fish and were somewhat smaller (18 per ounce) at planting time than the domestics (13 per ounce). These factors could have adversely affected the survival of the steelhead.

Their survival to the angler of 18.2 percent makes the 1955 plant of 5,470 Kamloops fingerlings one of the more successful of the Castle Lake rainbow plants. The Kamloops were considerably more responsive to fly fishing than the domestic strain. In 1957, 14.8 percent of the Kamloops catch was taken on flies, whereas only 8.4 percent of that year's catch of the 1956 plant of domestic fish was fly caught (difference significant at 0.5 percent level). H. D. Boles (unpublished data) made comparable findings in an experiment in the Lakes Basin Recreation Area of Sierra County, California. In his study, over 50 percent of the catch from a plant of catchable-sized Kamloops was taken on flies, while only 15 percent of the catch from a comparable lot of catchable-sized domestic rainbows was taken by fly fishermen. Judging from unsolicited comments from anglers and from personal experience, the Kamloops also exhibit a fighting ability superior to that of domestic strains.

The results of this single Kamloops plant suggest that this rainbow may be of considerable value in a well-rounded trout lake management program. Additional experiments in other lakes appear warranted.

Since 1959, Dr. Charles R. Goldman of the University of California at Davis, working in cooperation with the California Department of Fish and Game, has been employing the carbon-14 method in an attempt to determine the element or elements that are limiting primary productivity in Castle Lake. It was decided that future plants should be of identical number and strain, so that the effects of anticipated experimental fertilization techniques could be evaluated more readily.

Because of its suitability to the lake and because more data have been obtained for the Mt. Shasta fall-spawning domestic strain than for any other strain in Castle Lake, this strain has been chosen for annual stocking during the new phase of the Castle Lake investigations.

Size of Rainbow Fingerling Plants

It is believed that a valid estimate of the proper number of rainbow fingerlings to plant annually in Castle Lake may be made from the data now accumulated. It appears that a yield of roughly 13 pounds per acre may be expected from Castle Lake with the brook trout-rainbow trout combination (Table 1). With a catch composition similar to that of 1958 and 1959, approximately 2,000 rainbows averaging 0.2 pounds each must be caught, in addition to the brook trout, to provide an annual yield of this magnitude. It was stated earlier that four truck plants of undrugged domestic fingerlings produced a mean return to the creel of 20 percent. Therefore, the size of the plant may be determined simply by dividing the required catch (2,000) by the expected fraction returned (0.20). This results in an estimate of 10,000 for the number of rainbow fingerlings to be stocked annually, or 210 fingerlings per surface acre. All plants of the current phase of the investigation will be of this magnitude, beginning with the 1959 plant. It will be shown later that the proportion of rainbow in the Castle Lake catch in 1958 and 1959 was too great. However, a reduction in the proportion of rainbow in the catch will not invalidate the above procedure; it

TABLE 4

Castle Lake: Growth and Annual Catch of Rainbow Fingerling Plants, 1955 Through 1959

Planting date	Number and strain	Mark	Planting size	Average size (inches) and number caught at various ages			
				I	II	III	IV
8/ 9/54	5,000 RT-FS	BV	13 /oz.	6.67″ (942)	8.44″ (297)	10.66″ (36)	9.50″ (1)
9/17/54	5,000 SH	Ad-BV	18 /oz.	5.84″ (24)	7.96″ (150)	10.05″ (33)	9.23″ (14)
7/ 7/55	5,470 RT-K	Ad-RP	16 /oz.	6.63″ (303)	8.27″ (658)	9.15″ (15)	9.39″ (16)
8/14/56	14,858 RT-FS	RV	19 /oz.	6.40″ (2,007)	8.37″ (1,705)	9.14″ (638)	
8/16/57	5,477 RT-FS	Ad-RV	16.1/oz.	6.32″ (34)	7.92″ (81)		
8/16/57	4,523 RT-FS	Ad-LV	9.3/oz.	6.70″ (67)	7.66″ (193)		
7/28/58	20,000 RT-FS	LV	20.9/oz.	6.96″ (1,158)	--		
				6.61″	8.28″	9.26″	9.32″

will only reduce the required catch and, consequently, the size of the plant.

Growth of Rainbow Trout

With minor exceptions, the growth rates of the various experimental rainbow plants are similar (Table 4). The fish do not become appreciably vulnerable to the fishery until they approach six inches in fork length. The faster growing fish of this size begin to enter the catch in numbers in late June or early July of the season following their planting (at Age I). Their average length at Age I is 6.6 inches. At Age II and III the catch averages 8.3 and 9.3 inches in fork length, respectively. The few fish that survive more than three seasons exhibit growth increments of less than one inch per year. Rainbows larger that 11 inches are rarely caught in Castle Lake. It should be noted that these data are for angler-caught fish and, therefore, only approximate the actual growth rate of the fingerling plants. For example, the fact that the faster growing fish are the first to become vulnerable results in an overestimate of the average size of the fish at Age I.

Comparison of Rainbow and Brook Trout

Table 1 shows that an average annual yield of 10.3 pounds per acre was realized during the brook trout phase of the investigation (1947-51). In 1954 the yield of brook trout was also 10.3 pounds per acre and they comprised 84 percent of the total catch. Ninety percent of these brooks were wild, naturally-spawned fish. In 1958 and 1959, during the rainbow trout phase, the yield was 12.8 and 12.9 pounds per acre, respectively, and 73 percent of the fish were rainbows. This represents a mean increase in yield of 119 pounds per year (2.5 pounds per acre) over that of the brook trout phase. However, some of this increased yield was not an actual gain. The plants that contributed most heavily to the rainbow catch in 1958 and 1959 (the 1956, 1957, and 1958 plants) averaged 14,953 fingerlings per year or 1.1 pounds per acre per year. Thus, the net yield (pounds harvested minus pounds planted) of the rainbow phase exceeded that of the brook trout phase by only 1.4 pounds per acre.

When this increase is considered only in terms of cost, it becomes clear that management patterned after that of the rainbow trout phase of the Castle Lake investigations is not desirable for lakes of this type. The gross annual increase in yield of 119 pounds of trout was brought about by annual rainbow plants averaging 14,953 fingerlings at a cost of one cent each (Ward and Kier, 1959). Thus, the increased yield resulting from the fingerling rainbow plants cost $1.26 per pound.

This increase in yield was costly, since the heavy rainbow stocking established a rainbow population chiefly at the expense of, not in addition to, the naturally-produced brook trout population. The proportion of brook trout in the Castle Lake catch dropped from 84 percent in 1954 to 27 percent in 1959 (Table 1). Furthermore, 11 percent more brooks were caught in 1958 than in 1959, even though the 1959 catch had a 20 percent greater total weight. This may indicate that the proportion of large (old) fish in the population is increasing and that recruitment is inadequate.

Competition between brook and rainbow trout is believed to be a major cause of the decline of the brook trout population in Castle Lake.

If one hypothesizes that the chance of survival to the angler of a naturally-spawned brook trout fingerling is approximately equal to that of a hatchery rainbow fingerling, the proportion of brooks and rainbows in the catch will reflect the proportion of fingerling brook trout produced and rainbow fingerlings stocked. Therefore, if the number of rainbow fingerlings planted exceed the number of brook trout fingerlings produced, in time the catch will be comprised chiefly of hatchery rainbows. In Castle Lake, where spawning areas for brook trout are limited, it seems reasonable that the annual production of brook trout fingerlings would indeed fall short of the average number of rainbows stocked during this phase of the investigation.

The returns of fingerling plants of brooks and rainbows indicate that rainbows were the more cannibalistic of the two species. The 1948 plant of 20,000 fingerling brooks returned 36.4 percent to the angler, even though this plant was made when the lake was overpopulated with brooks longer than 6.0 inches in fork length. In contrast with this, plants of fingerling rainbows made when the population of large rainbows was high generally exhibited poor survival to the angler. It was stated earlier that the poor survival of these plants was believed to be due primarily to predation by the larger rainbows. It is also believed that predation by rainbows on newly-emerged brook trout has been another major cause of the decline in the brook trout population in Castle Lake since 1954.

The relative importance of rainbow predation and competition in the Castle Lake fishery is not known; however, a reduction in the size of the annual plant of rainbow fingerlings could be expected to reduce both, thereby benefiting the brook trout.

It should be possible to determine the size of rainbow fingerling plants that would allow the brook trout to attain a satisfactory population in Castle Lake. Perhaps this smaller-sized plant could bring about the same increase in annual yield as the larger plants that have been made during the rainbow trout phase of the investigation. Ideally, the rainbow plants should be of a size that would allow a near maximum population of naturally-produced brook trout and, therefore, would increase the annual yield without appreciably retarding the production of brook trout. If this did occur, the brook trout-rainbow trout combination could be maintained at reasonable cost.

Most western lakes of the Castle Lake type are relatively inaccessible and are subject to very light fishing pressure. Under these conditions, self-sustaining brook trout populations generally provide excellent fishing. It must be concluded that, when spawning tributaries are absent, such waters can be more economically managed with wild brook trout alone than with hatchery supported brook-rainbow populations.

SUMMARY

1. Experimental lots of marked fingerlings were stocked in Castle Lake annually from 1952 through 1958. These experimental plants were evaluated by means of a total (1952 and 1953) and a five-day-per-week creel census (1954-1959).
2. The primary objectives of the rainbow trout phase of the Castle Lake investigation were to determine (1) the effect of the rainbow

on the brook trout fishery; (2) the strain of rainbow that would provide the highest returns to the angler commensurate with a good growth rate; and (3) the number that should be stocked annually to provide the best returns to the angler.

3. Secondary experiments with catchable-sized and subcatchable-sized rainbows, planting methods, diets, and tags were carried out, also. The significant results of these tests were:
   a. The mean return to the angler of four plants of catchable-sized, fall-spawning, domestic rainbows was 79.9 percent.
   b. The percentage returned to the angler of a plant of 2,500 rainbow trout, weighing 7.8 per pound, was slightly better than the return from an equal lot weighing 13.1 per pound. However, in terms of weight stocked, the smaller fish gave a substantially higher return.
   c. In addition to their more efficient use of the lake's fish producing potential, plants of small-sized trout are more economical. The cost in the creel of catchable-sized rainbows ($0.19 each) is almost four times as much as the cost of fingerlings ($0.05 each) in Castle Lake.
   d. The return to the angler from air plants was appreciably less than that acheived through truck planting in Castle Lake.
   e. A plant of 3,833 untagged rainbows, 5.0 per pound, returned significantly better than 980 of the same lot tagged with an experimental subcutaneous tag.
4. Angling success during the rainbow trout phase was high, with the catch per angler hour averaging 1.0 trout. Fishing pressure dropped appreciably after 1957, due probably to deterioration of the Castle Lake road and the recent development of good trout fishing in nearby Dwinnell Reservoir.
5. Due to insufficient data, a decision regarding the best strain of rainbows for Castle Lake was not reached. However, in order to minimize variability during anticipated lake fertilization experiments, the temporary choice of a single strain was necessary. The domestic fall-spawning strain was chosen because of its suitability to the lake and because more data have been obtained for it than for the other rainbows tested in Castle Lake. The single plant of Kamloops rainbows showed considerable promise. Further experiments with them appear warranted.
6. Under a species catch composition similar to 1958 and 1959, 10,000 rainbow fingerlings appear to be the proper number to stock in Castle Lake annually. This amounts to 210 fish per surface acre.
7. The annual yield during the rainbow trout phase was greater than that during the earlier phases. However, the actual gain in yield (pounds harvested minus pounds planted) during the rainbow phase over that of naturally-produced brook trout was only 1.4 pounds per acre.
8. The gross increase in yield (119 pounds per year or 2.5 pounds per acre per year) brought about by the stocking of rainbow fingerlings was found to cost $1.26 per pound.

9. This increase in yield was costly, since the heavy rainbow stocking established a rainbow population chiefly at the expense of, not in addition to, the naturally-produced brook trout population.
10. The steady decline of the brook trout population since 1954 is believed to be due primarily to competition brought about by heavy rainbow stocking and predation by large rainbows.
11. Most western lakes of the Castle Lake type are relatively inaccessible and are subject to very light fishing pressure. Under these conditions, self-sustaining brook trout populations generally provide excellent fishing. It must be concluded that, when spawning tributaries are absent, such waters can be more economically managed with wild brook trout alone than with hatchery supported brook-rainbow populations.

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NOTES

NEW NORTHERN RECORD FOR BLACK SKIPJACK *(EUTHYNNUS LINEATUS)*

On September 2, 1960 a black skipjack was taken on trolling gear off San Simeon, California, approximate lat. 35° 20′ N.; long. 121° 40′ W., by Mr. Warren Beadle and Mr. Ken Butler of the albacore vessel *DOR ANN*. The fish weighed nine and one-half pounds and had a fork length of 602 mm.

Black skipjack are common off Mexico and Central America, but had been reported from California waters only twice previously: in July 1939 one was taken with a catch of bluefin tuna by a purse seiner operating near Santa Barbara Island; the second was caught by a sport fisherman off Dana Point during July 1951.

The present specimen is especially notable because it extended the known range of black skipjack northward by about 110 miles.

FIGURE 1. Black skipjack, *Euthynnus lineatus* Kishinouye.

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John C. Nowell, Marine Resources Operations, California Department of Fish and Game, December 1960.

TWO UNUSUAL CEPHALOPODS TAKEN NEAR MONTEREY

A male flapjack devilfish, *Opisthoteuthis californiana* Berry, was taken in about 250 fathoms off Monterey Bay, March 4, 1960 by Captain Dom Grillo of the Monterey trawler *TWO BROS. G. II.* This was only the second male reported from the California coast. The species was described in 1949 on the basis of two adult females trawled off Eureka in April 1948 (Berry, 1949). The first and only previous male was caught off Eureka over three years later in September 1951 (Berry, 1955). It had a lateral spread of about 7 inches, whereas the Monterey Bay male was 11 inches across the webbed arms. Its occurrence off Monterey extends the known range about 240 miles to the southward.

A giant squid, *Moroteuthis robusta* (Verrill), measuring $8\frac{2}{3}$ feet in total length was taken near Carmel, California, June 19, 1960. Jerry Stuguen, Mike Evans and Warren Kent of San Jose captured it while skindiving. It is the fifth giant squid known to have been taken in California waters. Previously, they have been reported from Monterey Bay (Phillips, 1933) and Laguna Beach (Croker, 1934). In addition, Prof. Rolf L. Bolin, Hopkins Marine Station, Pacific Grove, noted one at the Monterey fish markets, perhaps in the year 1935 and one was trawled off Santa Rosa Island by the Department of Fish and Game research vessel, *N. B. SCOFIELD*, in November 1954 (Figure 1). Neither of the last two has been reported upon in a scientific journal.

All but one of the California captures was made in shallow water, close to shore. The one taken off Santa Rosa Island in 1954 was trawled from a depth of 200 fathoms. The five California specimens have ranged from $8\frac{2}{3}$ to 10 feet in length, including tentacles. A giant squid 14 feet long has been taken in Alaskan waters. They were first described in 1876, from specimens taken off the Aleutian Islands, Alaska.

Another squid found off California which closely approaches the giant squid in size is the jumbo squid, *Dosidicus gigas*. Jumbo squid

FIGURE 1. Giant squid, Moroteuthis robusta, 116 inches total length, trawled in 200 fathoms off Santa Rosa Island from *N. B. SCOFIELD*, November, 1954. *Photograph by Jack W. Schott.*

up to four feet long have been noted in our waters but in Peruvian waters 10-footers are not uncommon. They appeared in tremendous numbers along the California coast during the years 1934-1937, and proved to be a pest to fishermen (Clark and Phillips, 1936 and Croker, 1937). Since then they have rarely been taken inshore, although albacore fishermen occasionally encounter them in some abundance well offshore.

Giant squid can be distinguished from jumbo squid by the prominent hooks on the terminal portions of the two, long, tentacular arms. The other eight arms bear suckers only. In the jumbo squid, none of the 10 appendages bears hooks; but, the suckers may be provided with horny rings. In the giant squid, the series of hooks on each tentacular arm is preceded by an oval "fixing pad", which is raised at the anterior margin. Each pad bears several small suckers. When the two pads are placed together, the hooks on the terminal portions of the arms form an effective food-capturing mechanism.

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—Julius B. Phillips, Marine Resources Operations, California Department of Fish and Game, August, 1960.

RANGE EXTENSIONS FOR TWO CALIFORNIA FISHES, WITH A NOTE ON A RARE FISH

On July 16, 1959, a 22-inch coral-red rockfish, *Sebastodes macdonaldi* (Eigenman & Beeson), was taken in a drag net fishing on the bottom in 110 fathoms off Pt. Sur, lat. 36° 18′ N., long. 122° 04′ W. It was in a catch of bocaccio and chilipepper rockfish made by the trawler *TWO BROS. G. II,* Captain Dom Grillo. Previously, the northern limit of the range for coral-red rockfish was Santa Monica Bay (Phillips, 1957). Therefore, the above capture extends the range about 250 miles to the northward.

On September 22, 1959, an 11-inch blacksmith, *Chromis punctipinnis* (Cooper), was taken with baited hook in five fathoms of water in Carmel Bay, lat. 36° 33′ N., long. 121° 56′ W. It was left at Marty's Market, Monterey, by a sport fisherman from the party-boat *NEW ROZ.* The northern limit of the range, previously listed as Pt. Conception (Roedel, 1953), is extended about 150 miles.

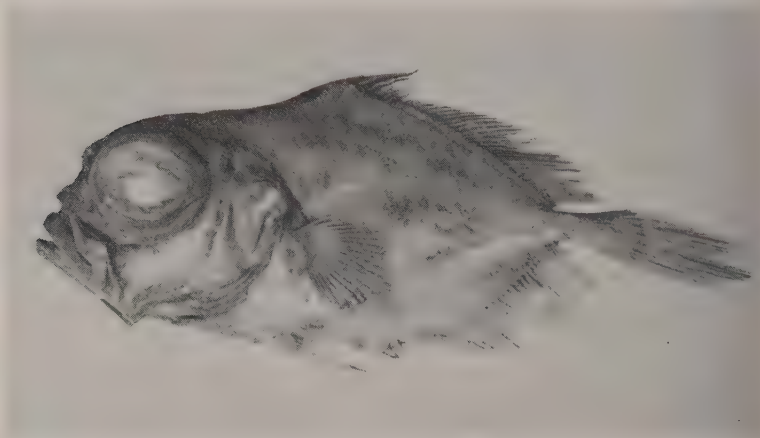

FIGURE 1. Popeye dory, *Allocyttus folletti* Myers, (7¾ inches total length) taken October 5, 1959, in 270 fathoms off Point Gorda, California. *Photo by J. B. Phillips.*

A rare oreosomatid, the popeye dory, *Allocyttus folletti* Myers, was taken on October 5, 1959, in 270 fathoms off Pt. Gorda, lat. 40° 16′ N., long. 124° 40′ W. This specimen, seven and three-quarter inches long (Figure 1), appeared in the net of the dragger *NORTHERN LIGHT,* operated by the Urbani brothers of Fort Bragg. Two other popeye dories have been taken in California waters off Eureka and Fort Bragg.

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—Julius B. Phillips, Marine Resources Operations, California Department of Fish and Game, July 1960.

AN INEXPENSIVE WELL MICROTOME FOR LABORATORY USE

Frequently in laboratory work concerning fisheries investigations a need arises for a microtome. The microtome here described (Figure 1) is inexpensive to build, simple to operate, and can be constructed with the aid of a drill press and a small metal lathe.

This instrument is similar in design to a hand microtome, but differs in that it utilizes a depth micrometer as the adjusting device, and has legs to facilitate its use.

The specifications and dimensions are flexible and may be modified to fit specific needs.

List of Parts and Materials

Items and Dimensions	*Number Required*
Tool steel body, 3 x 1½ inches	1
Steel piston (dowel pin), ⅜ x ¾ inches	1
Steel legs, ½ x 6½ inches	3
Aluminum hold-down clamps, ½ x ½ x 1-inch	2
Allen cap screws, 6–32 x 1-inch	2
Allen set screws, 6–32 x ¼-inch	3
Depth micrometer with 0- to 1-inch rod	1
Plastic razor blade holder	1
Single-edge razor blade	1

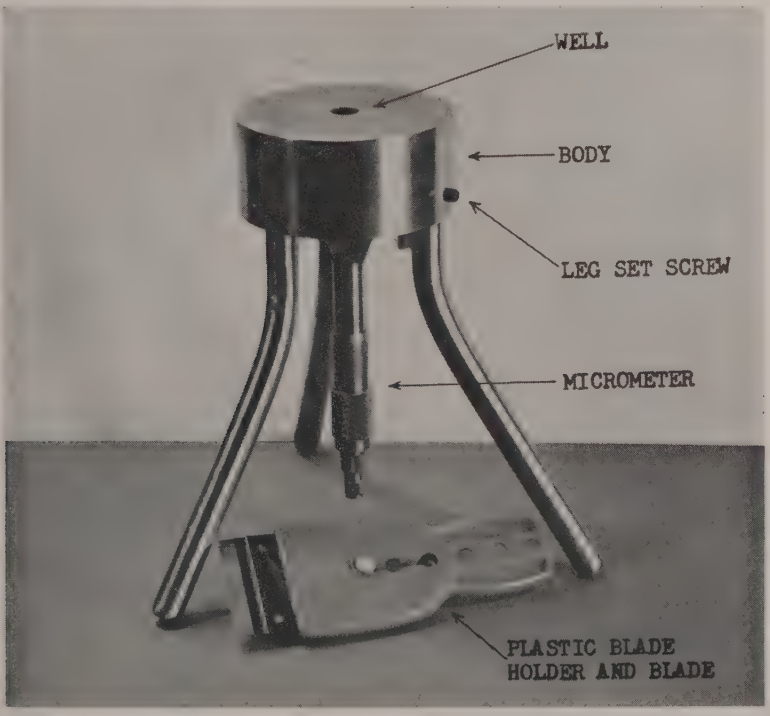

FIGURE 1. Microtome and knife. *Photograph by A. E. Vogel.*

CONSTRUCTION AND USE

The body of the microtome is tool steel 3 inches in diameter by $1\frac{1}{2}$ inches thick and has through its center a $\frac{3}{8}$-inch cylinder (well) fitted with a steel piston. The depth micrometer is attached to the underside of the body with two small "L" type hold-down clamps secured with 6–32 x 1-inch Allen cap screws. The legs are $\frac{1}{2}$-inch diameter steel and slightly bent for stability (Figure 1). They are anchored to the body in 1-inch deep holes and are made fast with 6–32 x $\frac{1}{4}$-inch Allen set screws.

The microtome knife is a standard single-edge razor blade held in a plastic blade holder.

Material to be sectioned is imbedded in a supporting medium such as pith-wood or a vaseline-paraffin mixture and placed in the microtome well. A preliminary cut made in the area to be sectioned will smooth the surface. Subsequent cuts can be made by adjusting the micrometer to the desired thickness.—*Robert A. Iselin, Marine Resources Operations, California Department of Fish and Game, January 1961.*

RETIREMENT

EARL LEITRITZ

Earl Leitritz, who served as supervisor of the California hatchery program for many years, retired from State service on August 4, 1961.

Leitritz's entire career was associated with fish hatcheries. His boyhood love for fishing steered him to his first regular job at Mt. Shasta Fish Hatchery, California, where on July 21, 1923, he went to work as an apprentice fish culturist, under the tutelage of the late Captain G. H. Lambson. Mt. Shasta Hatchery at that time was known as the largest fish hatchery in the world. Fish were distributed throughout the State by two specially equipped railroad fish cars. Leitritz spent the greater part of two seasons as a car messenger on the fish cars. After completion of his apprenticeship, he continued as a fish culturist until May 1, 1931, when he was promoted to Fish Hatchery Foreman, in charge of Fall Creek Fish Hatchery and egg collecting stations on the upper Klamath River, in northern California. In this assignment, he directed the salmon and steelhead trout operations in that area: collection of eggs, salmon and steelhead rearing, and distribution of the young fish.

In June, 1939, he was promoted to Fish Hatchery Superintendent, in charge of Mt. Shasta Hatchery, where he remained for a little over two years. In October, 1941, he was promoted to Fish Hatchery Inspector for northern California, with headquarters at San Francisco. The position title of Fish Hatchery Inspector was changed to Assistant Supervisor of Fish Hatcheries on March 1, 1942.

On January 26, 1943, Leitritz began a 31-month tour of duty with the U. S. Army. On his discharge from the Army, August 6, 1945, he returned to his former position with the then California Division of Fish and Game.

On September 8, 1947, he was promoted to Supervisor of Fish Hatcheries, to direct all fish hatchery operations in California. During the period 1949 through 1952, he was the Department's fish hatchery expert in carrying out a $4,300,000 fish hatchery expansion and modernization program. His many original ideas in hatchery design and layout established California as a leader in the field.

On reorganization of the old Division of Fish and Game into the present Department of Fish and Game in 1952, his position was reclassified to that of Fisheries Management Supervisor, and he moved from San Francisco to Sacramento March 1, 1953, when the headquarters location was changed.

Leitritz is well known throughout fish cultural circles for his writings on hatchery subjects. He has been a periodic contributor to *The Progressive Fish Culturist, Outdoor California, California Fish and Game*, and *U. S. Trout News*. Some of his publications have been reproduced

in England and France. His latest publication, *Trout and Salmon Culture (Fish Bulletin 107)*, has received international acceptance as the definitive treatise on trout and salmon culture and is presently being translated into Japanese.

After retirement, Leitritz will devote his time to consultation work for a Seattle company manufacturing fish cultural equipment, to the development of his 520-acre ranch in Surprise Valley, Modoc County, California, and to his long-time hobby of restoring antique automobiles. His colleagues and many friends wish him well in these endeavors.—*Walter T. Shannon, Director, California Department of Fish and Game.*

RETIREMENT

DONALD D. McLEAN

Donald D. McLean, Game Manager III, retired from the Department of Fish and Game on June 30, 1961 after 34 years of service. He is a native of Mariposa, California.

Prior to joining the then Division of Fish and Game, he collected biological specimens in southeast Arizona and adjacent Mexico and served four years as Assistant Park Naturalist at Yosemite National Park.

His career with the Department encompassed virtually all phases of game research and management. However, his special interest was in research. He was gifted with exceptional powers of observation and his general knowledge of California wildlife was unequalled in the Department. His varied interests are reflected in his writings. Notable are a game bulletin on the quail of California, a booklet on upland game, and various articles in CALIFORNIA FISH AND GAME on deer, antelope, waterfowl, and mountain lions.

He is an accomplished artist and his drawings and sketches of birds and mammals have appeared in numerous Department publications.

Mr. McLean was active in organizations outside the Department, being a permanent member of the Board of Governor's of the Cooper Ornithological Society and a life member of the California Academy of Sciences.

His co-workers and many friends in the Department extend best wishes for a long and happy retirement.—*Ben Glading, Chief, Game Management Branch, California Department of Fish and Game.*

BOOK REVIEWS

Ecology of Inland Waters and Estuaries

By George K. Reid; Reinhold Publ. Co., New York, 1961; xvi + 375 pp., $9.

This is the best introductory text for limnology this reviewer has seen. The roles of geology, chemistry and biology in their broadest sense are presented in a logical sequence.

The text is divided into five sections, the first of which is a discussion of how lakes, streams and estuaries are formed and maintained. It is concerned with what might be called geohydrology. Water is discussed as a modifier of landscapes.

The second section is quite brief and is concerned with the physical and chemical features of water itself.

The third section discusses water as an environment, including such aspects as solar radiation, thermal characteristics, movements, and dissolved gases and solids. Each of the topics is discussed in terms of lakes, streams, and estuaries. The subject is first thoroughly covered in terms of lakes. The same characteristics are then reviewed in terms of streams and estuaries.

The fourth section is a review of the kinds of organisms found in the three aquatic environments. This section is perhaps of least interest and usefulness. It is rather more general than the rest of the text would dictate. A more extensive bibliography would be helpful. A number of excellent general references on aquatic animals have not been included.

Part five introduces ideas concerning the relationship of organisms and environment and although it is shorter than one would have expected, it is quite adequate. There is an interesting introduction to the use of radioactive tracers in limnological studies. This, however, is a field that is developing so rapidly that the most important advances are still to be found in "occasional papers." The treatment, however, is adequate for the group this book is written for.

The illustrations are generally good, well reproduced, and demonstrate what they are meant to demonstrate. There is a good bibliography and the book is well indexed. The general makeup of the book is of high quality.

If I were teaching limnology, I would certainly use ECOLOGY OF INLAND WATERS AND ESTUARIES. I would recommend the use of this book as a refresher for old students and as an introduction to the field of limnology for new students.—*J. B. Kimsey, California Department of Fish and Game.*

Ring of Bright Water

By Gavin Maxwell; E. P. Dutton, 1960; x plus 211 pp., 78 black and white photographs, $5.

The author of this book is a very versatile man: prose writer and poet, portrait painter and photographer, naturalist and keeper of wild and domestic pets, linguist and student of his fellow men, and one-time shark fisherman. He has written books about his shark fishing experiences, about the Marsh Arabs of Southern Iraq, about the Sicilians. The greater part of the present book is laid at his home on a remote sea loch on the northwest coast of Scotland. He sees with the eye of an artist and naturalist, and describes what he sees with the tongue of a poet—an ideal combination. He has an appreciative and discerning eye for sea and sky and plant life, for wild birds and dolphins and seals and fishes, for all the color and life about him. Most of all, his book concerns his pet otters.

Having lost his dog companion of many years, the author started looking about for another pet to keep him company, and thought of an otter. In the marshes of Southern Iraq he found a baby one, which died after a few days but left him convinced that this was indeed what he wanted. Shortly afterward, he acquired a second one, Mijbil, which he brought home with him to London, and later to his cottage in Scotland. After Mijbil's accidental death a year later, he made great

efforts to find another otter, and eventually secured his present one, Edal, who had been brought from West Africa.

Otters are fascinating animals, with very lovable personalities and with a wealth of interesting habits. They are not, however, easy to keep. They enjoy human companionship, and demand a great deal of it if raised as pets. They have definite minds of their own: you do not own an otter, the otter owns you. An otter is either asleep or else engaged in almost ceaseless activity, much of it play. About Mijbil's first being turned loose with a bathtub of water, the author says: "For half an hour he went wild with joy in the water, plunging and rolling in it, shooting up and down the length of the bath underwater, and making enough slosh and splash for a hippo. This, I was to learn, is a character of otters; every drop of water must be, so to speak, extended and spread about the place; a bowl must at once be overturned, or, if it will not overturn, be sat in and sploshed in until it overflows. Water must be kept on the move and made to do things; when static, it is as wasted and provoking as a buried talent." Again, he says, "A room is not properly habitable to them until they have turned everything upside down . . . I had never really appreciated the meaning of the word ransacked until I saw what an otter could do in this way. . . . An otter must find out everything and have a hand in everything; but most of all he must know what lies inside any man-made container or beyond any man-made obstruction." If all this makes even a confirmed pet-lover and longtime otter-admirer such as the reviewer feel that after all maybe she *could* do without keeping an otter herself, she still feels that there are few more fascinating things to read about than Maxwell's pets. Also, the book is illustrated with 78 beautiful photographs, which add greatly to its appeal.—*Anita E. Daugherty, California Department of Fish and Game.*

Soil and Water Conservation

International Union for Conservation of Nature and Natural Resources, Seventh Annual Technical Meeting, Athens, Greece, September 1958, vol. 4, 374 pp., $5.

This volume contains the papers presented at a symposium on "The influence of soil and water conservation on natural resources".

Thirty-three papers are included dealing with a diversity of subjects. All, however, are related to an examination of the effect of various conservation measures on the aquatic environment.

There is an introduction to the theme and a summary of the two background papers by Umberto D'Ancona. One background paper, "The effect of various conservational measures or works on the aquatic environment and on the stocks of that environment", was prepared by P. A. Larkin. The other, titled "Methods of minimizing the deleterious effects of water-and land-use practices on aquatic resources", was authored by William A. Dill and G. L. Kesteven. The balance of the volume is composed of experience papers ranging from general surveys of a problem, such as "Multiple-purpose planning for aquatic resources", by O. Lloyd Meehean, to very specific papers, such as "Modern fish passes in the Netherlands", by C. L. Deelder. Nearly all the papers are of high quality.

The use of water for hydroelectric development, irrigation, domestic supplies, navigation, and waste disposal is considered by workers from many backgrounds. Some of the countries represented are Canada, Sweden, Ireland, Southern Rhodesia, Congo (Belgian), Holland, Italy, Austria, Denmark, Kenya, and the United States. This volume is a significant contribution to water resource development in its broadest sense. It will very probably not have the wide use it deserves.

Nearly all of the people participating in the symposium were engaged in finding remedies for the effects of water developments that were beneficial in one sense, such as the development of hydroelectricity, but detrimental in other respects such as interference with fish migrations. Great advantages have been obtained from water conservation schemes, and many have created new aquatic resources of great value. There are numerous examples of resources of great value being destroyed by short-sighted one-purpose project planning.

A few of the contributors to the symposium are apparently employed by government or private agencies directly engaged in the development of water resources. Most are with government agencies charged with the responsibility of ameliorating the harmful side effects of development or finding ways to enhance the existing aquatic resource, without significant interference with the primary development. The latter group, until recently, was a minority. Their role in resource planning is now becoming more important, and many agencies engaged in development now

request their presence and assistance in early planning stages. This volume, however, points out on a global scale that despite advances "there is nevertheless evidence that needless damage is being done with consequent serious losses, economic, nutritive, recreational, scientific and esthetic". It recommends: That all projects throughout the world affecting aquatic environments—either directly or indirectly—should, at the planning stage, be integrated with a program of investigation that would secure the preservation of aquatic species and communities and improvement of living resources.

The volume may be purchased from the International Union for Conservation of Nature and Natural Resources, 31 Rue Vautier, Brussels 4, Belgium.—*J. B. Kimsey, California Department of Fish and Game.*

Western Forest Industry

By John A. Guthrie and George R. Armstrong; The Johns Hopkins Press, Baltimore, Maryland, 1961; xxvi + 324 pp., 52 fig., 55 tabl., $6.50.

Logging in its various aspects is important to biologists dealing with salmon and steelhead along the Pacific slope of North America. Fortunately, there seems to be a growing realization that abnormal siltation resulting from careless logging and other improper land uses may be one of the most critical factors in the welfare of trout and salmon in Western streams (*cf.* Cordone and Kelley, The Influences of Inorganic Sediment on the Aquatic Life of Streams, Cal. Fish & Game, vol. 47, April, 1961). Trends in the Western forest industry have an important bearing on the future welfare of salmon and trout fisheries. This book provides a wealth of information about the current logging picture and about the anticipated future trends. Projections of things to come are based on a well-documented analysis of present circumstances, including many excellent tables and graphs. The distribution and nature of the present timber resource from Alaska to California is outlined in much detail, along with a full statistical description of the related industries. Separate attention is given to the three main segments: Lumber, pulp, and plywood.

The author's approach is analytical and thoughtful, throwing many interesting lights on the logging situation which will help non-foresters to better understand the industry, past, present, and future. The following quotation concerning apparent trends illustrates very well the sort of material in this book which will interest fishery biologists: "The decade of the 1950's has shown that lumber production can be maintained and even increased while numbers of mills are decreasing. Normal increases in production in the West between now and 1975, barring war and depression and similar major disturbances, need not, therefore, call for large increases in numbers of mills. Nor is there evidence of mills tending to grow significantly larger. The most notable change has been increasing mill concentration in the fairly narrow belt running through northern California, eastern Oregon and Washington, northern Idaho, and northwestern Montana. To the west of this belt, concentration of timber lands in the hands of large wood-using firms, timber holding companies, and speculators, and competition for sawtimber by other firms and industries have decreased timber availability, pushed stumpage prices up, and reduced chances for profitable operation of the small mill. To the east of the belt, problems of timber availability are currently less important than problems of transportation and marketing.

"These are not transient influences. They are tied to the general economic development of the West. Over a period of years, in the interior states, the gradual growth of industry and commerce will help to overcome some of the obstacles to operation of the small mill. By contrast, further economic development of the coastal states, and further blocking up of timber lands by larger well-established firms will tend to restrict the establishment of small mills in the coastal forests. The rate of change will not necessarily be rapid, nor involve large numbers of mills, nor induce widespread industry migration. The outlook, in the light of the experience of the past twenty years, would seem to be largely one of gradually diminishing mill concentration in coastal Oregon and in north coastal California with further development in the inland areas of these same states, and eventually in the interior states, by mills generally of medium size."—*Alex Calhoun, California Department of Fish and Game.*

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